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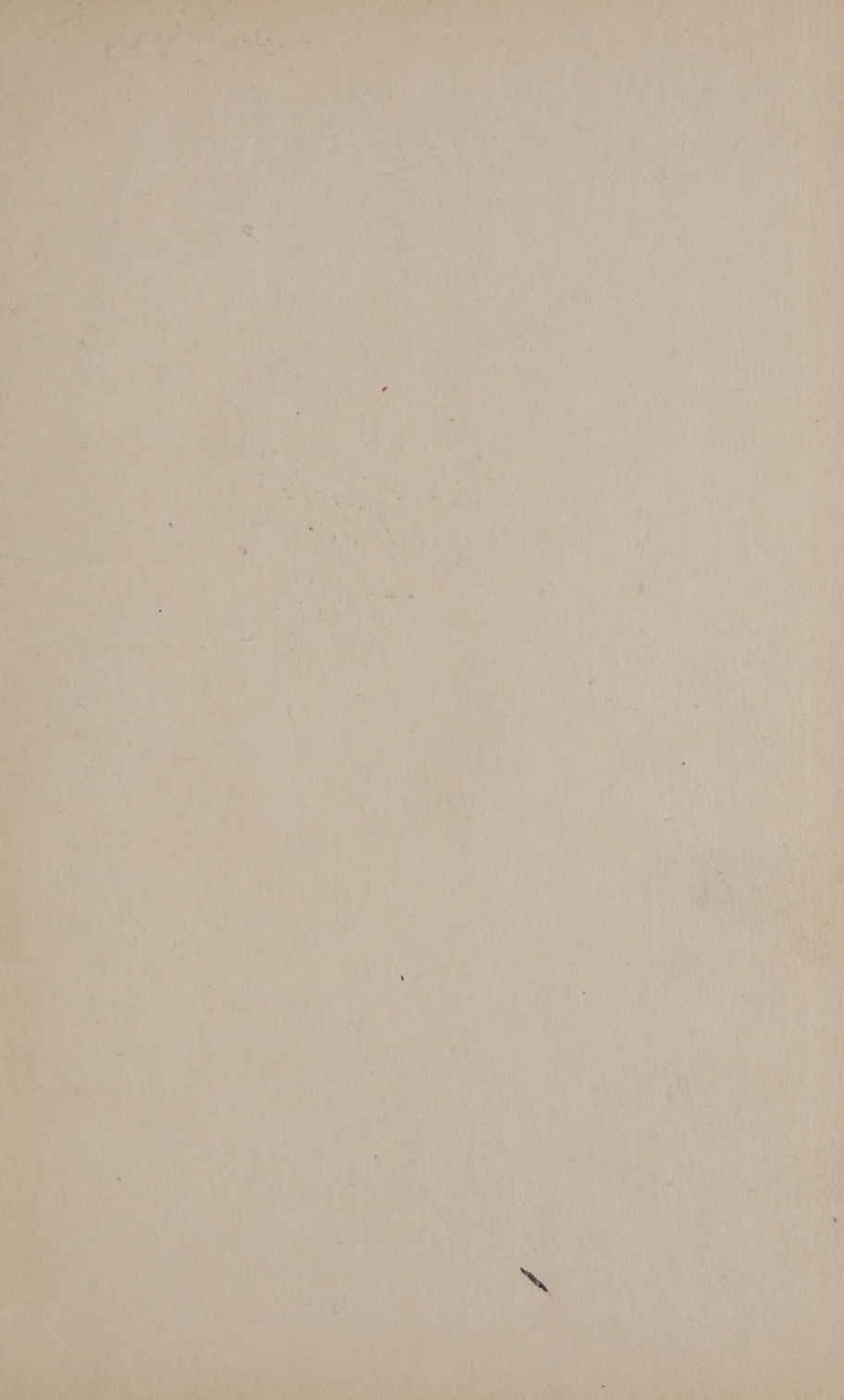
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A. C. RADIO GUIDE

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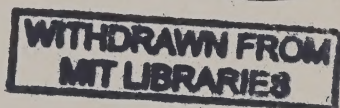
A. C. Radio Guide

*A Practical Treatise on Alternating-Current Radio Tubes
and Sets and Dynamic Loud Speakers*

By

Kenneth A. Hathaway

Radio Technical Advisor, The Chicago Daily News



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INTRODUCTION

A GREAT many books have been published on various phases of radio practice, but few of them have been specifically planned to give the reader in concise form a knowledge of alternating-current radio.

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¶ In the present book the author takes up in detail the various types of tubes and the power units which are used in connection with alternating-current sets. He also describes in detail some of the latest models, such as the Bosch "28," Majestic "70," Stromberg-Carlson "635," and Tyrman Imperial "80." There is a section devoted to the conversion of the direct-current set to one using alternating-current tubes.

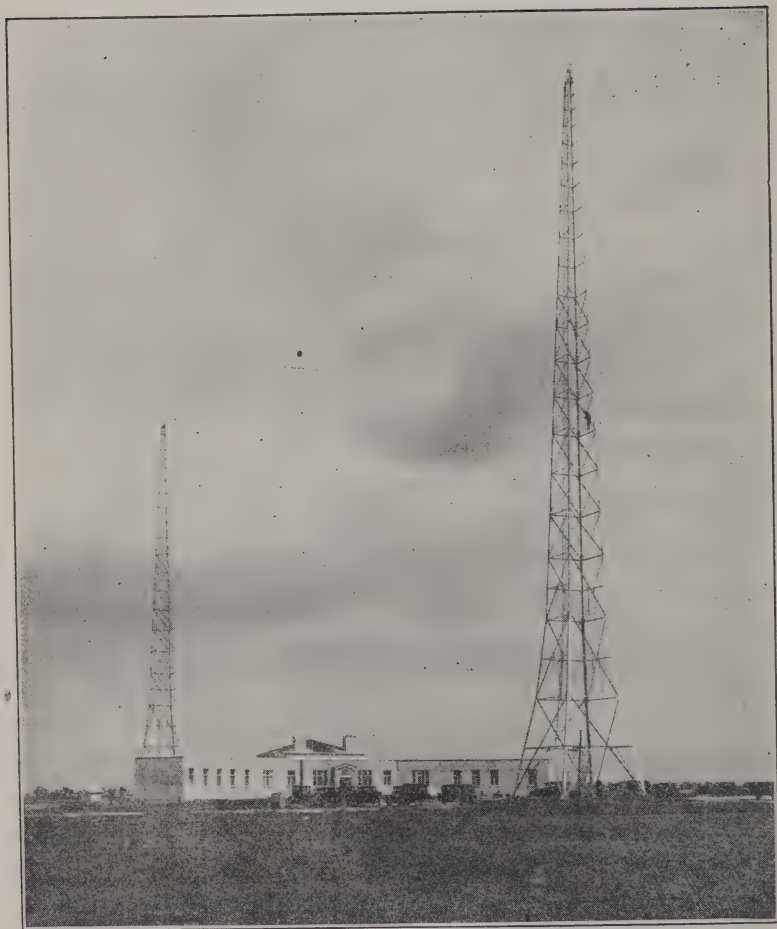
¶ The man who is interested in getting the greatest efficiency out of his own receiving set and is also planning to enter the service field of maintaining commercial sets will get many practical helps from the section devoted to trouble shooting.

¶ With the increasing interest that is being shown in short-wave reception, that is, that portion of the radio band below 200 meters, the reader who is interested in this newest form of radio work will find much practical material both on short-wave reception and short-wave receivers.

¶ The development of the loud speaker has kept pace with the rapid change in the other parts of radio equipment, and the section given to the dynamic speaker is perhaps the latest word on this most important device. Both the balanced armature type and the type which uses the voice coil are discussed in detail.

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ALTERNATING-CURRENT RADIO SETS

In the discussion of alternating-current radio sets there has been no attempt to go into the engineering details of radio. Rather it has been the aim to present the subject in such a manner that radio service men and those not so well acquainted with electrical and radio engineering may have a clear view of the ordinary principles involved in modern radio receiving sets.

TUBES

It has taken several years to bring the vacuum tube as it is known today from the embryonic stage to a high-class product. It was conceived prior to the time when its adaptation to radio circuits was considered. In order that a better view of the situation may be given, it seems well to provide a historical background to this study.

History shows that in 1883 Thomas A. Edison discovered that a secondary circuit could be established within a vacuum tube by placing a positive charge upon an external plate element and passing a current through a filament wire within the confines of the tube. Twenty-one years later in 1904 Edison's discovery was put to use when J. A. Fleming of London found that a tube constructed with a carbon filament and a separate plate could be used in the detection of radio frequency currents. The tube then became known as the Fleming valve, and at the present time vacuum tubes are referred to as valves in England.

Lee De Forest, an American engineer and inventor, is credited with having made the next step in the development of the vacuum tube when he found that by inserting a third element he could control the amount of current that passed between the filament and the plate, thereby making the tube an amplifier as well as a detector. The third element was named the grid on account of its appearance.

After De Forest's contribution to the tube field and until 1925 tubes had been constructed so that battery equipment was neces-

sary to furnish the power to light the filament as well as to supply the charge to the plate element. A great deal of experimental work was carried on with a view to eliminating the batteries. Plate supply units were designed and successfully operated, but the filament battery eliminator presented such great problems that the engineers turned their attention to the development of a tube that would operate with alternating current.

The first alternating-current tube that appeared in 1925 was designed by an engineer named McCullough. It was a tube of the heater type, that is, one in which the filament element did not itself serve as the electron emitting element, but acted to heat an element, known as the cathode, from which the electrons were emitted. Further experimentation showed that an alternating-current tube having a filament for the emission of electrons could be used as an amplifier, but a heater type of tube was necessary in detection.

The shield grid tube, known also as the shield plate or the screened grid tube and given the designation UX-222, is a later development. This tube contains four elements, the object of the fourth element being to form a shield between the plate and the grid to prevent feed back. The alternating-current type of shield grid tube is usually of the heater type.

Nomenclature and Purpose of the Parts of a Vacuum Tube. The elements that go to make up the vacuum tube are called the filament, the plate, the grid, and, in the case of the shield grid tube, the shield or outer grid.

The filament forms a complete circuit through the tube and utilizes two terminals on the base. It is made of special resistance wire treated or coated with a substance that has a high electronic emission. Voltages varying from 1.5 volts to 15 volts are used to supply the current to the filament.

The plate of the tube is in the output circuit. It is the element to which a positive charge is delivered from the B battery or other source of supply through the primary inductance or resistance.

The grid element is a perforated or coil-shaped element that is inserted between the plate and the filament for the purpose of controlling the action between the filament and the plate. The grid is in the input circuit of the tube.

The stem is the glass bell-shaped support for the elements of the tube. The entire tube assembly is sealed into the base, a bakelite shell with four or five prongs to which the elements are connected, the number depending upon the type of tube and the number of connections to be made to the tube.

In the case of the alternating-current tubes of the heater type where an electron emitting element is used, the extra part is called the cathode but it is not considered a separate element. It is a part of the grid circuit in the radio set.

The tubes thus far referred to are those used in radio reception and are known as general purpose tubes. In addition, there are

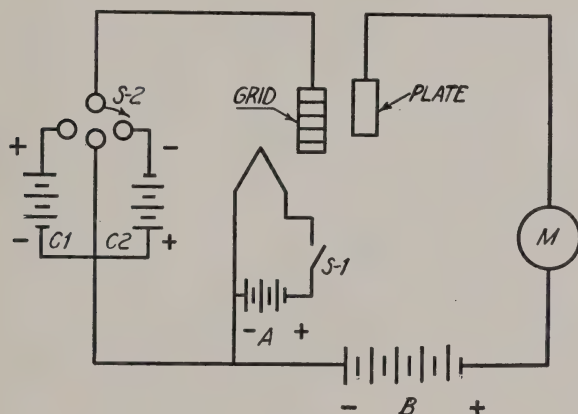


Fig. 1

the rectifier tubes that are as essential to radio operation as the ones used in the amplifier and detector stages.

Fundamental Action of the Vacuum Tube Used in the Radio Circuit. It is not the purpose of this discussion to show the engineering details governing the use of vacuum tubes, but rather to briefly explain the action and use to which the radio tube must be adapted. In order that a better understanding may be had of all tubes, it is best to show the action of a simple tube used with batteries.

In Fig. 1 the elements of the vacuum tube are shown schematically in the relationship that they hold in the tube itself. Notice the grid element is located between the filament and the plate just as they are in the actual tube. Regardless of how they may appear

on a circuit diagram they should always be visualized as having the relationship shown in the drawing.

Before going into the three-element tube, which is the one in common use today, it is well to look into the action of the two-element tube developed by Fleming. The grid element had not yet been introduced into the tube so that there was only the filament and the plate, as shown in Fig. 2.

Like charges repel, and unlike charges attract, is a rule that should be kept in mind in studying the action of the vacuum tube.

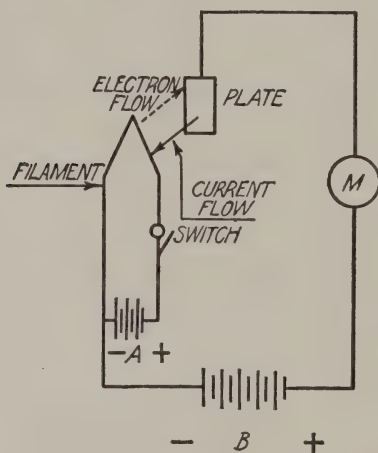


Fig. 2

A few facts taken from the molecular theory are necessary to fully understand the reason for the tube action. All metals are said to be made up of parts called molecules. Each molecule is divided into still smaller parts known as atoms. Scientists have never been able to break up the atom, but the theory has been accepted that each atom consists of a group of electrical charges, a positive charge forming the nucleus while a group of negative charges surround it. Under ordinary conditions the molecules take a definite form and vibrate with a constant speed. Applying heat to the metal causes the molecules to vibrate more rapidly so that the color of the metal changes and at the same time the negative electrons attain a speed too great to keep them confined within the metal and they are given off into free air.

Not all metals have the property of emitting a large number of the electrons. In the matter of tube development it was necessary to find a substance that would emit the maximum number of electrons under the conditions in which they must operate. After much experimenting, tungsten wire treated with thorium was used, the thorium having the effect of producing a high electronic emission. Later tubes utilize forms of oxides, the oxides being coated upon the filament wire. The filaments treated with the thorium are known as thoriated filaments and can be rejuvenated by burning the filament without a plate connection so that no current is flowing through the tube. The oxide coated filaments are not rejuvenatable, but it is often possible to renew their life by setting them away for a few weeks, in which time the molecules making up the oxide coating rearrange themselves so that the negative charges of the atoms are grouped around the positive nucleus.

An electrical current forms the heat source for the radio vacuum tube. Referring to Fig. 2 notice that two batteries are provided in the circuit. The purpose of the A battery, otherwise known as the filament battery, is to heat the filament element of the tube so that the electrons will be emitted.

As long as there is no charge on the plate element there can be no current flowing through the plate circuit. Another battery, marked B, is connected so that the negative terminal of the battery is common to the negative terminal of the A battery. The positive terminal of the B battery is connected through the milliammeter to the plate of the tube. By means of this battery a positive charge is placed upon the plate.

Closing the switch in the filament battery the filament becomes heated and the electrons fill the space in the tube. Following the rule that unlike charges attract, the negative charges are attracted to the positively charged plate. These charges literally hit against the plate and bound off into space eventually returning to the filament element to be given off once more.

Not all the electrons that are emitted by the filament reach the plate, however, due to a condition set up inside the tube known as the space charge. Due to the positive charge upon the plate a number of the electrons are attracted to that element; but when the space between the filament and the plate is filled with the

negative charges, some of those negative charges have the effect of repelling other negative charges that are being emitted by the filament, driving them back to the filament and sometimes back into the filament wire. It is necessary to overcome the space charge in order that the plate current may flow. Increasing the plate voltage serves to attract more of the negative charges so that they have no opportunity of repelling other charges.

Secondary emission is another phenomenon within the tube that must be eliminated. If the plate element becomes heated to a sufficiently high temperature, it, too, emits electrons with the result that there is a flow of negative charges not only from the filament to the plate but also from the plate to the filament. Sufficient radiating facilities eliminate secondary emission. Nickel is usually used in plate construction due to its low electronic emission.

But the current does not flow through the tube from the filament to the plate. The electronic stream forms a path for the current to follow, so that the current is flowing through the tube from the plate to the filament.

The two-element tube can be used as a detector or a rectifier. But in view of the fact that further development placed a grid between the filament and the plate, the three-element tube containing a filament, grid, and plate is used exclusively and there is no object in going into the circuits using the two-element tube.

The grid element is made in the form of a coil supported by two wires sealed into the stem. Its purpose is to control the flow of electrons from the filament to the plate and thereby control the flow of current in the plate circuit. Normally a negative charge is placed upon the grid in all stages except the detector. A third battery, known as the C battery, which is connected in the grid circuit, is shown in Fig. 1.

In order to show the action of the grid a switching arrangement has been provided at *S-2*. Also two batteries are shown in the circuit, one with the negative terminal toward the grid of the tube and the other with the positive terminal toward the grid. The opposite terminals of each battery together with a connection straight through are connected to the negative of the filament battery. In this way we are able to place a positive or negative charge upon the grid as well as a zero potential. The difference between the

voltage applied to the grid with respect to the filament is known as the grid bias.

The value of the plate current is dependent upon the voltage applied to the filament, the voltage applied to the plate, and the voltage applied to the grid.

Assume that the full operating voltage is applied to the filament so that it is functioning at full efficiency. Place the switch arm on the center tap so that there is no grid bias and the grid is at what is known as zero potential. The current through the milliammeter will take a definite value. Throw the switch arm to the right so that the charge on the grid is negative, the plate current will immediately drop; and if a variable resistance were connected in the grid connection so that the voltage could be gradually decreased, the plate current would be found to become greater as the value of the grid voltage became less. Move the switch arm over to the left so that the grid is given a positive charge, and the value of the plate current will be found to increase. Similarly, if the rheostat were connected into this circuit, the plate current would be found to increase with an increase in the value of the positive bias.

Assuming that the charge upon the grid is negative, the electrons that are emitted by the filament are stopped in their flight toward the plate and a part of them are repelled because the polarity of the charges is the same, and the electrons return to the filament. Due to the reduced path between the filament and the plate a higher resistance exists between the two elements so that a smaller amount of current is allowed to flow.

When the charge on the grid is made positive, that element too has the property of attracting a number of the electrons. Being in mesh form some electrons pass through it to the plate so that both the grid and the plate pass current to the filament.

The current that is impressed upon the grid of the tube in a radio receiver has the same characteristics as any other alternating current. The difference lies in the number of alternations that are made each second. The grid element is accordingly acted upon alternately positive and negative. Depending upon the intensity of the impulses the voltage on the grid is varied so that the plate output is also varied to correspond to the variation in the input circuit. Having the property of rectification, the output of the tube is not

an alternating current, but rather is a pulsating direct current. It is changed to an alternating current as it passes through the transformer to the next tube.

Determining the Value of the Grid Biasing Resistor. The value of the grid biasing resistor in alternating-current circuits is determined by using the normal current draw in the plate circuit of the tube as the value of I and the grid voltage desired as E in Ohm's law, $E=IR$. Take as an example a single stage of radio frequency using a type 227 tube where a plate supply of 90 volts shows a plate current of .0035 of an ampere. It is desired to obtain a negative bias of 5 volts. Substituting in the equation we find that $5=.0035 R$. Dividing it is found that a resistor of 1429 ohms would give the correct bias. For all practical purposes, however, a resistance having a value between 1400 and 1500 ohms would be found satisfactory.

Tube Characteristics. By tube characteristics is meant the specifications as to voltages and the performance of the tube under different values of voltage applied to the elements.

The filament voltage is the electrical pressure that is applied to the filament terminals of the tube.

The filament current is the amount of electricity that is drawn by the filament. The ampere is the unit of measure.

Plate voltage is the electrical pressure that is applied to the plate element.

The plate current is the measure of the amount of electricity consumed by the plate circuit, measured in milliamperes.

The grid voltage is the electrical energy that is applied to the grid and is otherwise referred to as the grid bias or biasing voltage.

The amplification factor of a tube, otherwise known as the μ , represents the maximum number of times the tube is capable of amplifying the signal that is impressed upon the grid. The value of the amplification factor varies with the value of the voltages applied to the elements.

Grid resistance, also known as the input resistance and impedance, represents the resistance in the circuit between the grid and the filament. Anything that tends to retard the flow of the grid current is regarded as input or grid resistance.

The plate or output resistance refers to anything that tends to retard the flow of the current between the plate and the filament.

The mutual conductance of a tube represents its ability to act as an amplifier and is a measure of the amount of energy that is conducted through the tube.

The power in watts indicates the maximum amount of power that is available under the best adjustment of voltages.

Amplification Factor. The amplification factor of a vacuum tube is determined by the circuit shown in Fig. 3. Notice that the grid and plate voltages are variable. Make a reading of the milliammeter in the plate circuit when the voltage applied to the grid is zero. At the same time take a reading of the plate voltmeter to indicate just what voltage was necessary to give the milliamperere reading. Turn the rheostat in the grid circuit until the voltmeter shows that a 5-volt bias is being delivered to the grid. Note and record the reading on the milliammeter. Return the grid voltage

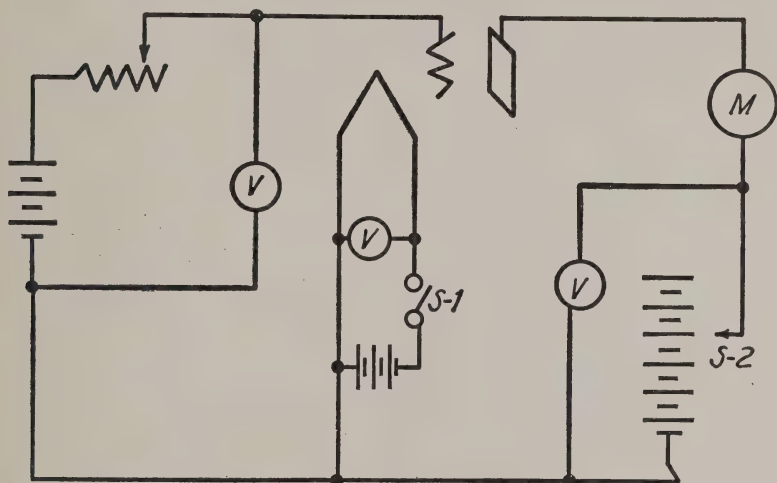


Fig. 3

to zero and move switch *S-2* in the plate circuit until the same reading is obtained on the milliammeter as was obtained when the grid voltage was applied. Record the value of the plate voltage. Dividing the value of the plate voltage required to make a definite change in the current by the number of volts applied to the grid to obtain the same current drain will give the value of the amplification factor. It represents the relationship of one volt of grid bias to a certain change in plate voltage. If the amplification factor of a tube is 8, then one volt of grid bias has the effect of 8 volts of plate battery.

Plate Resistance. The value of the plate resistance is obtained by dividing the voltage applied to the plate element by twice the plate current, the readings being taken when the grid voltage is zero.

Plate Impedance. The plate impedance is found by dividing a given change in the value of the plate voltage by the change in current that it causes. As an example, if it is found that a change of 10 volts in the plate supply causes the milliammeter to change its reading from .002 of an ampere to .001 of an ampere, the difference is .001, which value divided into the 10-volt change shows a plate impedance of 10,000 ohms.

Mutual Conductance. Conductance is exactly the opposite of resistance and is a measure of the conductivity of an electrical current. The unit of measure of conductivity is called the mho. The mutual conductance of a vacuum tube is obtained by dividing the amplification factor by the plate resistance. A tube that will serve as a good amplifier is one which will show a high mutual conductance. It is seen, therefore, that a good amplifier tube must be one which has a low plate resistance and a comparatively high amplification factor. The value of the amplification factor need not be high if the plate resistance is low, and this is the condition under which the power amplifier tubes operate. The characteristic chart will show them to have an amplification factor lower than the standard type of tubes.

Internal Capacities. Internal capacities, of which there are three, are a source of annoyance in the design of radio circuits. They have no definite value, and in fact no two tubes of the same type can be said to be identical so far as this characteristic is concerned. The elements of the tube, suspended as they are with a definite relationship with the other elements, set up capacity effects just as though they were condenser plates. Not only the elements serve to establish a capacity value, but the leads from the base through the stem, and the prongs as well.

So we find that there is a capacity between the filament and the grid, between the grid and the plate, and between the plate and the filament. The diagram in Fig. 4 shows the capacities as they exist in the tube, the diagram at the right placing them outside the tube so that their effect upon the circuits may be better determined.

Each of these capacities has a decided effect upon the directing of the radio frequency currents through the tube, due to the fact that high frequency alternating currents can pass through condensers by reason of the rapid charging and discharging of the plates.

None of the internal capacities cause more disturbance than that from the plate to the grid. The presence of this capacity permits the transfer of energy through the tube in the direction opposite to that intended. The consequent feed-back, as it is called, is very detrimental to the action of the radio receiver. The neutralizing condenser used in the neutrodyne circuit has the effect of balancing out the effect of the capacity from plate to grid. It is necessary to change the setting of the neutralizing condenser each time the tubes are changed to obtain the best results.

The capacity between the grid and the filament has the effect of varying the value of the grid circuit. Since the internal capacity

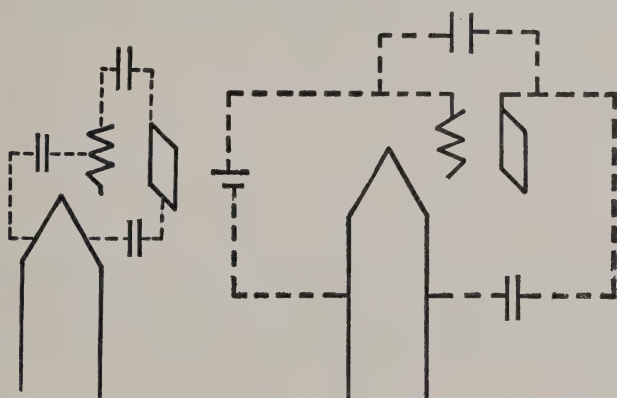


Fig. 4

is so small, the effect is negligible. The value of the capacity varies slightly with the frequency of the current impressed upon the grid. In the Sparton circuit this change is put to use in a special automatic tuning device that is affected by the change itself.

The plate to filament capacity is not detrimental, serving to aid in the by-passing of the radio frequencies to the plate return or negative filament circuit.

Direct-Current Tubes. The principal direct-current tubes in use are those of the UX-201-A and the UX-199 types. The 201-A is known as the 5-volt tube because it requires 5 volts to actuate the filament. The 199 is a three-volt tube and requires 3 volts of battery energy to actuate the filament.

Alternating-Current Tubes. The UX-226 and the UY-227 are the tubes that are used more extensively than any other alternating-current tubes. However, there are two other types of alternating-current tubes designed for use as detectors and amplifiers. One is that produced by the Kellogg Switchboard and Supply Company and the other is made by the Arcturus Radio Company. The UX-226 tube is designed for use as an amplifier and contains the standard elements, filament, grid, and plate. The UY-227 type tube is known as a heater tube because the filament circuit is merely a means of heating a cathode or electron emitting element. The UY-227 type of tube was primarily designed for use in the detector stage, but it serves equally well as an amplifier for either the radio or the audio stages. The arrangement of various parts of the 226 and 227 types of tube is shown in Fig. 5.

UX-226 Tube. The filament voltage for the 226 type of tube is specified to be 1.5 volts. The tube will operate efficiently with a supply as much as .6 of a volt below that specified and a supply as small as .1 of a volt above that specified will result in the tube having a short life. Therefore, it is desired that the transformer to supply the tube be made to furnish a mean voltage, approximately 1.35 volts, to the tube terminals.

There are two types of fields that are set up in the type 226 tube, an electrostatic and an electromagnetic. While these fields exist in all tubes, it was not until the alternating-current tubes were introduced that there was reason to consider them other than to eliminate them as much as possible in the construction of the tube. An increase in the filament voltage has the effect of increasing the electrostatic field and decreasing the electromagnetic field. A decrease in the voltage acts vice versa. Therefore, it was necessary to reduce one or the other of the fields to a negligible quantity. The electro-static field can be eliminated by a shield such as that used to hold the electron emitting substance in the heater type of tube. But the type 226 tube has no such shield, so that it was necessary to lower the voltage until the electrostatic field was negligible. The effect of the electromagnetic field is balanced out of the circuit by means of a resistor having a value of 6 ohms or more connected across the filament terminals. Due to the fact that the grid of the tube is usually given a negative bias, it is necessary that the so-

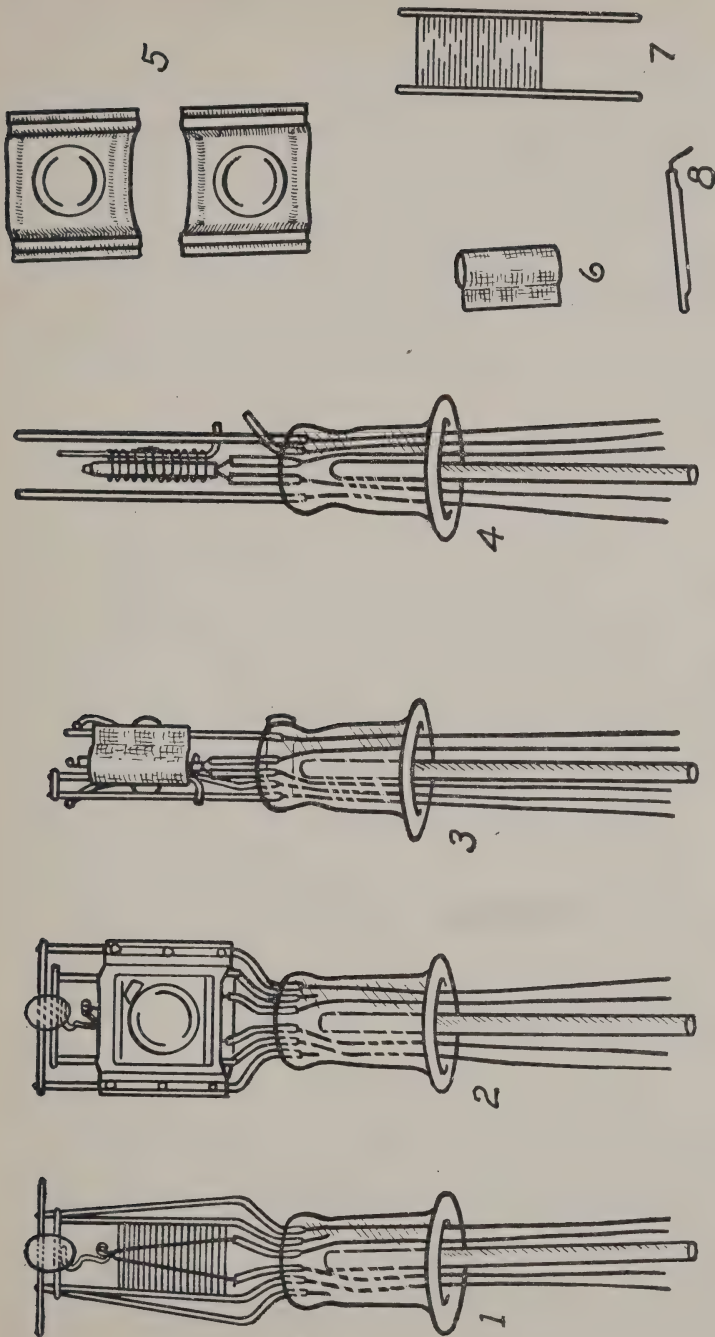


Fig. 5

1. Filament and grid of 226 type tube
2. Stem assembly of 226 type tube
3. Stem assembly of 227 type tube
4. Filament and grid of 227 type tube
5. Plate element for 223 tube
6. Plate element for 227 tube
7. Grid element for 226 tube
8. Filament of 227 tube

called center tap of the shunt resistor be placed slightly off center. When alternating-current tubes were first introduced it was thought that a center tapped secondary winding on the transformer would serve to balance out the effect of the electromagnetic field, but that method was abandoned when it was found that the field was not balanced out at the mechanical or the electrical center of the circuit.

The allowable plate voltage specified by the manufacturers is 180 volts, though it is usually used with a 90-volt plate supply. The 180 volts is specified for use with a $13\frac{1}{2}$ -volt grid bias when the tube is used in the last audio stage. Its use as the final amplifier is not recommended, however.

It is sometimes desired to use the 226 type of tube in audio stages with a plate supply of 135 volts. In such cases the grid voltage should be from 9 to 12 volts.

UY-227 Tube. The construction of the UY-227 tube differs from that of the 226 type. The plate and the grid elements are cylindrical in shape and the plate is perforated, as shown in Fig. 5.

The construction of the filament element in the 227 differs from that of other tubes in that it loops through an oxide coated isolantite bushing, taking the form shown in Fig. 5. The isolantite is cylindrical so that the other elements take the same form in order that a constant relationship may be maintained between all elements. If the grid and the plate were oval in shape, the electrons emitted by the cathode would not be evenly distributed on the plate and the action of the tube would vary decidedly. The cylindrical form is the most convenient form in which to make the isolantite filament support.

Surrounding the isolantite is an oxide coated shield which serves to emit the electrons. The grid element is next in the assembly, followed by the plate on the outside of the grid.

In the construction of a vacuum tube, after the elements are sealed into position and within the bulb, the tube is placed on a vacuum pump and the air is removed. The best pumps known to science cannot remove all traces of gas from the inside of the tube, so that it is necessary to perform an operation known as bombarding. In doing this, the tube is surrounded by a coil carrying a high frequency electrical current. Any metal that is within the field generated by the coil becomes hot and if left in the field long enough

would become white and likely melt. Particles of gas that cling to the metallic elements in the tube are driven off by the heat. But since the plate of the 227 type of tube is so small in diameter, it would be difficult to reach all spots on the inside of the element, so that the plate is perforated to permit the penetration of the high frequency current as well as to provide an outlet for the gas. Located so close to the heater element a solid plate would cause a high secondary emission. The perforated plate serves to radiate the heat and prevents the emitting of negative charges from the plate.

The action of the heater type of tube is identical with all other tubes. The cathode serves as the grid and the plate return. It is usually given a negative bias with respect to the filament, though in some instances it is made positive.

The voltage to be applied to the filament of the 227 type of tube should not exceed 2.5 volts. In designing transformers it is better that provision be made for a maximum of 2.35 volts in order that the life of the tube may be materially lengthened.

The 227 tube will operate with plate voltages ranging from 45 to 180 volts. Not more than 90 volts should be applied to the plate when the tube is used as a detector and it is customary to use not more than 45 volts. Used as a radio or audio amplifier the tube should be given a negative bias of $4\frac{1}{2}$ to 6 volts, and the bias may be obtained individually by connecting a resistor in the lead between the cathode and the ground to which the grid circuit is returned.

Power Tubes. In the construction of alternating-current sets it is customary to use what is known as a power tube in the final stage of audio amplification. The power tubes are not designed to give added volume to the reproduction, but to provide a higher undistorted output so that more volume may be obtained from the reproducer with less interference or distortion. The amplification factor of the tubes is lower than that of the standard amplifier tubes.

The power tubes are known as the 112, 112-A, 171, 171-A, 210, and 250 types of tubes. The 112 and the 112-A are identical except that the 112-A supersedes the 112 and uses .25 of an ampere for the filament supply instead of the .5 of an ampere used by the 112. The same condition exists with respect to the 171 and the 171-A types of tube, the 171-A consuming .25 of an ampere of filament

current while the 171 uses .5 of an ampere. The 112, 112-A, 171, and 171-A tubes require a filament supply of 5 volts.

The plate voltage for use with the 112 and the 112-A is specified at 112.5 to 150 volts. The grid bias ranges from 9 to 12 volts, depending upon the plate voltage.

A supply of 135 to 180 volts is required for efficient operation of the 171 and the 171-A type tubes, with grid voltages ranging from 22.5 to 40.5 volts.

The 210 and the 250 type tubes are in reality power tubes, the 210 tube having a rated output of more than a watt, while the 250 type tube is rated at more than 4 watts. Both of these tubes require a filament supply of 7.5 volts while the plate voltage is specified as high as 425 to 450 volts. The grid bias voltages range from 40 to 80 volts, depending upon the value of the plate supply.

The construction of the power tubes is identical with that of other straight filament type of tubes. The difference in the characteristics is caused by the relationship between the elements of the tube and the different voltages delivered to the elements.

Kellogg Tube. The Kellogg type of tube is otherwise known as the McCullough tube. The characteristics of the Kellogg tube are very similar to those for the five prong tube of the 227 type except for the filament voltage. The Kellogg tube requires a filament supply of 3 volts. The filament terminals of the Kellogg tube are placed at the top of the tube. The plate and grid connections of the circuit are made at the standard plate and grid terminals while the cathode or grid return connection is made to either of the standard filament terminals.

Arcturus Tube. Reference is made here to the high voltage type of tube for which the Arcturus company is better known. The principle of the Arcturus tube is identical with that of any other heater type of tube, but it differs from the others in that it uses a standard four-prong socket and the cathode is connected directly to the filament circuit within the tube. Fifteen volts of alternating current is required to operate the tube as compared with 2.5 volts for the standard tube.

It has been found that the electro-magnetic field in a tube decreases as the voltage applied to the tube increases and that the electrostatic field increases with an increase in filament voltage.

Arcturus found that the electrostatic field could be effectively shielded out by the cathode element and that the field occasioned by a 15-volt supply to the filament was negligible. They connected one end of the cathode to a point slightly off the center of the filament circuit within the tube, that position having been found necessary just the same as the location of the tap for the shunt resistor across the filament of a 226 type of tube.

Other characteristics of the Arcturus tube follow those for the standard tubes, except that in the detector stage it is recommended that a positive bias of 3 to $4\frac{1}{2}$ volts be applied to the grid through what is known as a D battery. The D battery is the same as a C battery except that it is used in a different position. It is connected into the circuit by joining the negative terminal of the D battery to the negative side of the plate circuit and then connecting the grid return terminal of the radio frequency transformer to the positive terminal of the D battery.

Rectifier Tubes. There are two distinct classes of rectifier tubes, those known as the gaseous type and those known as the thermionic or filament type.

Gaseous Rectifier Tube. The gaseous rectifier tube has no filament element. The practical construction of the tube may be seen in Fig. 6. It will be noted that there are three terminals and that none of them forms a circuit. The two terminals that connect to the filament terminals of the socket are known as the anodes while the element that is connected to the plate terminal of the socket is called the cathode. The bulb of the tube is filled with gas after the air has been exhausted by means of pumps.

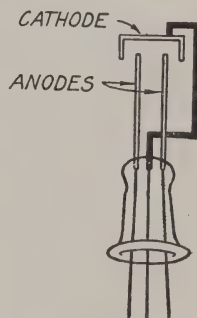


Fig. 6

The anodes of the tube are connected to the outer terminals of a transformer. The alterations of the current are taken consecutively by each anode and are transferred to the cathode through the gas. The gas is such that it will allow the passage of an electrical current in only one direction, with the result that a positive charge is obtained from the plate or cathode. The negative side of the line is obtained from a center tap of the winding furnishing the supply to the anodes. Refer to Fig. 13.

Thermionic Rectifier Tube. Any type of vacuum tube containing a filament and a plate, regardless of whether it contains a grid element, is a potential rectifier. If a tube of the 201-A type were to be used as a rectifier, as is often the case in small ham transmitting circuits, it is better to connect the grid and the plate together to give the effect of a single plate.

There are two types of thermionic rectifiers, the half-wave and the full-wave. The half-wave rectifier, known as the UX-281, is used in rectifier units furnishing the plate supply for tubes of the 210 or 250 type while the full-wave rectifier, the UX-280, is used when tubes of the 171 type are to be used in the power stage. The 280 type of tube has an output of 300 volts at 125 milliamperes while the 281 tube has a maximum output of 125 milliamperes at 700 volts.

The half-wave rectifier tube—the UX-281—contains a single plate and a filament element. The plate element of the tube is connected to the plate terminal of the tube socket while the filament terminals take their place in the standard filament terminals of the socket. A transformer having a secondary winding capable of delivering a maximum of 700 volts is necessary. Another winding must be provided to furnish the 7.5 volt filament supply. The filament winding should be center tapped, but it is not necessary that the high voltage winding have a center tap unless two tubes are used in the rectifier circuit. Refer to Fig. 14.

The filament terminals of the tube are connected to the terminals of the filament winding of the transformer. The plate is connected to one end of the high voltage winding. As the filament is heated, a stream of electrons is given off. These electrons being of a negative character attract the positive charge of the alternating current which collects upon the plate of the tube. The electronic stream forms a path over which the current may pass from the plate to the filament. The current then follows through the filament circuit to the center tap of the filament winding where it emerges as the positive side of the rectified current. The negative side of the circuit is obtained from the end of the high voltage winding opposite to the connection to the plate of the rectifier tube.

The full-wave rectifier tube—the UX-280—is identical in principle to the half-wave. The transformer for use with this tube

differs from that used with the 280 type tube in that the high voltage winding as well as the filament winding must be provided with a center tap. The outer terminals of the high voltage winding are connected to the plates of the rectifier tube, one of which makes contact through the plate terminal of the socket while the other makes contact through the grid terminal of the socket. Refer to Fig. 15.

The heating of the filament causes an electronic stream to pass to the two plate elements so that the positive portion of the alternating current is passed to the filament, emerging from the center tap of the filament winding as the positive side of the rectified current. The negative side of the circuit is obtained from the center tap of the high voltage winding. If one-half of the transformer were cut off so that one plate of the full-wave rectifier remained operative, the circuit would be found to be the same as that for the half-wave rectifier.

Shield Grid Tube. The shield grid tube contains four elements, the filament, the grid, the plate, and a shield. The shield is also referred to as the outer grid, while the grid is known as the control grid.

The construction of the shield grid tube is similar to that of the type 227 tube except that the fourth element is inserted. The filament of the tube extends through the center of the tube assembly and connects at the top and bottom. Surrounding the filament is a coil approximately an eighth of an inch in diameter which serves as the grid. Separated from the grid a short distance is another coil which forms one part of the outer grid or shield. The plate is perforated to prevent secondary emission due to the heat that is generated by the filament, and surrounds the section of the outer grid that is inserted next to the control grid. Surrounding the plate is another section of the outer grid in the form of a coil. The two sections of the grid are connected at the bottom by a metal washer so that the plate element is completely shielded.

The connections to the filament terminals of the tube are made through the standard filament terminals of the socket. The plate element is connected through the plate terminal of the socket, but the grid element is connected through a special terminal on the top of the tube. The grid terminal of the tube is provided at

the top of the tube in order that the capacity within the tube may be minimized.

The grid terminal of the socket is used to provide the connection to the outer grid. The shield serves to attract a number of the negative charges that are given off by the filament so that the space charge between the plate and the filament is materially reduced. It also reduces the capacity between the filament and the plate and between the grid and the plate. The capacity that is set up with the insertion of the shield results in a shield to plate capacity and a shield to grid capacity. Since the shield is connected independent of the plate, the capacity set up does not affect the circuit, and a higher theoretical amplification can be obtained.

Ventilation of Alternating-Current Tubes. A great deal of difficulty has been experienced in the use of shields surrounding tubes of the alternating-current type, particularly those of the heater type. The cause of the trouble was not apparent for some time, but was eventually found to be due to the lack of ventilation in the shield. The exceedingly high temperature from the heater element caused the grid and the plate elements to become hot enough to emit electrons so that varying paths of electronic streams were set up within the tube. In order to eliminate the trouble it has been found necessary to provide ventilation by drilling holes in the top and bottom of the tube shields to allow the heat to escape. Holes in the top of the shield will not suffice if there are none in the bottom to provide a draft.

POWER UNITS

Alternating current is adapted to the use of power supply units for radio operation more than direct current, due to the fact that the reversals of flow of the current permit the use of transformers to obtain higher voltages than those delivered through the power lines in the home.

The problem of making a successful power unit to replace the B batteries was not of any great moment. The main difficulty that was encountered was the failure of the condensers in the filter unit, but when this was overcome little or no trouble was found.

The condensers that are used in power supply units must be capable of withstanding higher voltages and currents than is

apparent on first glance. At the time the first eliminators were introduced, the engineers investigated the requirements of the tubes and found that ninety volts was required for the amplifier and that a maximum of 135 volts was sufficient to supply the plate of a power tube. The current drain was light compared to that on power line work. So specifications were drawn up that seemed to satisfy the purpose. But no one had taken into account the instantaneous changes in voltages due to the pulsations of the voice currents that passed through the circuit. And because of these pulsations and consequent sudden fluctuations in voltage and current, many condensers broke down. The result was that more attention was paid to the maximum voltages that would be impressed upon the plates of the condenser and the paper that was used as the dielectric was carefully inspected, so that today it is only occasionally that we hear of a condenser breaking down in power supply circuits.

Eliminators for the filament battery, however, did not fare so well. The trouble in this case was not only found in the condensers but also in the choke coils, the purpose of which was to filter out the ripple in the rectified alternating current in order to obtain as near a true direct current as possible. The most successful condenser that has been developed is that put out by Dubilier. Very little information concerning this condenser is available, except that it is what is known as a polarized unit. Once connected into the circuit, it should not be changed, since a charge is placed upon the plates and the condenser becomes, in addition to a capacity unit, a form of battery that aids in delivering the necessary current. The rectifier unit, to be in accordance with the desires of the radio public should be dry, and difficulty again arose because of the high current drain through the rectifier which, in a comparatively short time, paralyzed the rectifier and caused it to deliver a fluctuating current to the tube filaments.

In order that the subject of power units may be fully understood, it seems more feasible to discuss the different types of B eliminators that have been in use, many of which are still used in connection with a filament supply unit of some type, such as a battery with a trickle charger or an A eliminator that has been found to be successful.

A plate supply unit is composed of four distinct parts—the power transformer, the rectifier agent, the filter circuit, and the voltage divider circuit.

Power Transformer. The power transformer is for the purpose of changing the alternating current that comes in on the light lines from a supply of 110 to 125 volts to a current having a value as high as 500 or 600 volts. The present-day power transformers include separate windings to furnish the filament supply for the alternating-current tubes that have become so popular.

Rectifier Units. Different types of rectifier units may be employed according to the requirement of the set with which it is to be connected. The purpose of the rectifier is to convert the alternating current into a sort of direct current, but it does not complete the conversion of the alternating impulses into a current that even approximates that delivered by batteries. The rectifier has the property of allowing the passage of the current in one direction, but sets up a resistance such that it cannot flow in the opposite direction, thus keeping the current at one polarity.

Fig. 7 shows just what takes place when the alternating current has passed through a half-wave rectifier. The alternations above the zero potential line are the only ones left and they flow to a maximum positive, return to zero, hesitate during the other half of the cycle, shown by the dotted line, and then repeat the operation. The spaces between these alternations must be bridged by the filter circuit which consists of the chokes and condensers.

There is another type of rectifier known as the full-wave unit. The full-wave rectifier takes both sides of the cycle and further closes the gaps by inverting the alternations below the line and placing them between the alternations that would naturally be above the line. This is shown diagrammatically in Fig. 8.

Filter Circuit. The condensers and chokes in the filter circuit are shown schematically in Fig. 9. The condensers serve to close up the gaps between the alternations as shown in Figs. 10 and 11. When the current is passing from zero potential toward the positive direction, the plate of the condenser connected to that side of the line takes a positive charge. As the current begins its flow toward the zero line, the charge that has been stored up is released and the alternations take the form shown in Fig. 10. At this point

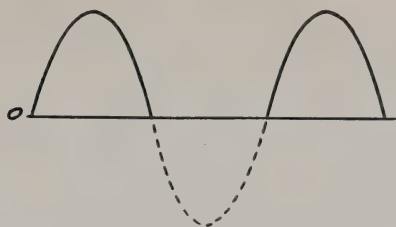


Fig. 7

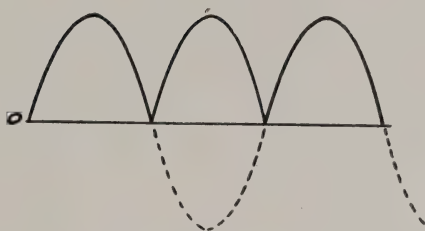


Fig. 8

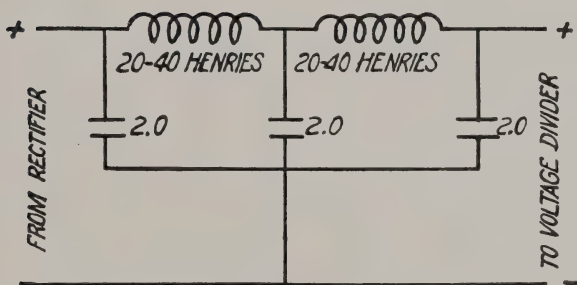


Fig. 9



Fig. 10



Fig. 11

the chokes come into play and by retarding the passage of the current at the high points, a resultant current is obtained about midway between the high and low points of the partially filtered current, as shown in Fig. 11. While it is very difficult to obtain a current that will be as constant as a battery supply, the output of a power unit is sufficiently steady to operate a radio receiver. The explanation given here is intended to show the effect of the filter on the alternating wave and does not take into account voltage differences, a discussion of which might confuse the average layman.

Voltage Divider Circuit. The output of a power supply unit is divided by means of the voltage divider circuit, which consists of a resistor bank connected between the positive and the negative side of the output. Taps are taken off the resistor at various points to provide the varying voltages that are required for different stages of the receiver circuit. The necessary values for the voltage divider circuit are determined by applying Ohm's law, $E=IR$, where E is the voltage difference, I is the current, and R is the resistance. The current-carrying capacity of the resistor should also be taken into consideration and determined from the equation $W=I^2R$, where W is the wattage dissipation, I is the current, and R is the resistance.

The voltage divider circuit may be of either the fixed or the variable type, according to the use to which it is to be put. If the power unit is to be used with a definite circuit in which the current draw from each tap of the output will always be the same, the various resistors may be given a fixed value; but if the apparatus is to be made adaptable to any type of receiver, the output must be arranged so that at least the critical voltages, such as those to supply the detector and radio frequency stages, may be varied to conform to the plate current required for each individual tap.

Glancing at the circuit diagrams for power supply units one will find that the values for the over-all divider circuit will vary between 1100 ohms and 25,000 ohms. In order that this may be fully understood, a diagram of the voltage divider circuit is shown in Fig. 12. Resistors are inserted between the negative side of the line and the various taps of the circuit to assimilate the current draw by the different portions of the radio circuit. It is desired to find the values of $R-1$, $R-2$, $R-3$, and $R-4$. The voltages to be

obtained are, reading from the negative side of the supply, 45, 90, and 135 volts, with a maximum value across the entire unit of 200 volts. The values of the resistors at R -5, R -6, R -7, and R -8 is immaterial, but the readings on the meters M -5, M -6, M -7 and M -8 must be taken into account. These readings are indicated by the figures to the right of each meter.

Between the negative lead and resistor R -1 another meter is placed, not as a part of the circuit, but merely to retain the numerical

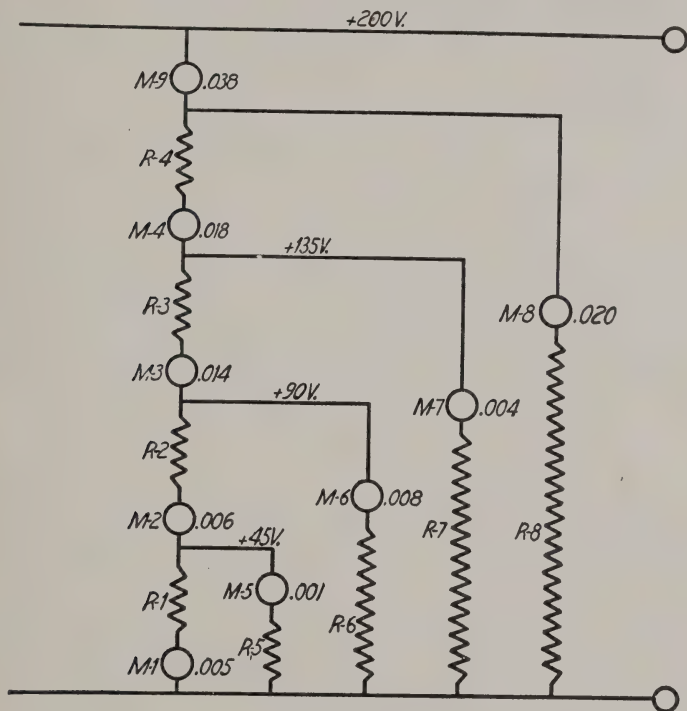


Fig. 12

values throughout the circuit. Between each pair of resistors another meter is assumed. These meters are to be disregarded so far as their physical installation in the circuit is concerned.

Before we can make any calculation of any kind we must make an assumption as to the amount of current that must be dissipated by R -1. In this case we are assuming that it will dissipate five milliamperes, or .005 of an ampere. At the right of meter M -1 we indicate the .005 of an ampere. It is desired that we obtain

45 volts for the detector plate supply. Since the calculation is made with Ohm's Law, $E=IR$, we find that

$$45 = .005 R$$

Making the calculation, $R-1$ should have a value of 9,000 ohms.

The value of $R-1$ is not used in the calculation for $R-2$. At the next tap we desire to get a value of 90 volts, but since we have already used 45 volts, it is necessary to use only the voltage drop in the calculation so that we again have a value for E of 45 volts. For I we have a different value, however. Meter $M-6$ shows that there is a current draw of .001 of an ampere at the 45-volt tap. This .001 of an ampere is to be added to the .005 of an ampere that is dissipated through $R-1$ and gives us a total of .006 of an ampere, as indicated at meter $M-2$, for the value of I in the determination of the value of $R-2$. Therefore

$$45 = .006 R$$

Making the calculation, $R-2$ should have a value of 7500 ohms.

In finding the value of $R-3$, we again take the voltage difference across the resistor, in this case 45 volts, and add the current indicated by meter $M-6$ to the value shown at $M-2$, giving a total value of .014 of an ampere. The equation then becomes

$$45 = .014 R$$

Making the calculation, we find that the value of $R-3$ should be 3214 ohms, but for practical purposes a resistor having a value of 3200 ohms can be used. Place the value .014 of an ampere opposite the meter $M-3$.

Subtracting 135 from 200 we find that there is to be a difference of potential of 65 volts between the terminals of $R-4$. We find also that meter $M-7$ shows a reading of .004 of an ampere and this value must be added to the reading of $M-3$, giving a total of .018, the value indicated opposite $M-4$. The value of E is 65 and the value of I is .018, so that we have

$$65 = .018 R$$

Making the calculation we have 3611 ohms, but here again we can disregard the odd figures and use a resistor of 3600 ohms.

The value of current to be dissipated must never be made so high that the output of the rectifier tube will be exceeded. The current drains for the various voltage taps are determined by multi-

plying the current draw of one tube by the number of tubes it is desired to operate at that voltage. Another meter indicated by *M-9* shows the total current passed through the divider and the circuit to be .038 of an ampere. This value is approximately the amount drawn by an ordinary set.

Classification of Power Units. Power units are classified according to the use to which they are to be put, and from that use is determined the type of rectification that is necessary to accomplish the purpose. There are two general types of rectifiers for plate supply—the electrolytic and the vacuum tube. There are two kinds of tube rectifiers—the gaseous and the thermionic. The gaseous rectifiers are those in which the alternating current is applied to the two anodes and the current passes through an ionized helium gas to the cathode, from which terminal the positive side of the rectified wave is taken. The thermionic type of tube is the one that employs a filament from which the electrons are emitted and passed to the plate. In the case of the thermionic tube the filament is the cathode and the plate is the anode, since the current flow is from the plate to the filament, opposite to the flow of the electronic stream.

A simple form of electrolytic rectifier may be made by inserting a lead and an aluminum bar into a solution made by dissolving ordinary baking soda or borax in water. The efficiency of such a rectifier is very low and it is short lived. The breaking down point is also very low and in order to adapt it to high voltage it would be necessary to use a large number of cells. The current that is passed through an electrolytic rectifier is regulated by placing a resistance in the alternating-current line. The Fansteel Products Company were the producers of a large assortment of electrolytic rectifiers, but in their construction they made use of an acid solution together with a tantalum alloy bar for one of the electrodes. The chemical content of their rectifier unit was never made available for publication.

An electrolytic rectifier acts to allow the passage of the current from one electrode to the other when the alternating wave is flowing in one direction, setting up a resistance to the flow in the opposite direction. The direction of flow is determined by the electrochemical characteristics of the metals used in the rectifier.

One metal is said to be electro-positive or electro-negative with respect to another metal as determined by the amount of the metal that is dissolved by the electrolyte when an electrical current is passed through it. No metal is electro-positive or electro-negative except with respect to another metal. As an example, lead and aluminum are often used in electrolytic rectification. According to data compiled in chemical laboratories approximately one-third of a gram of the aluminum is consumed while four grams of lead are being consumed by the same electrolyte with the passage of one ampere of current for one hour, regardless of the voltage. The aluminum is said to be electro-positive with respect to the lead.

When an electrolytic rectifier breaks down and ceases rectifying, it is made apparent by the appearance of sparks upon the positive post, the aluminum in most instances. It is necessary then to renew the elements and the solution. Impure electrodes will cause a quick breakdown in the rectifying action of the unit.

Vacuum tube rectification has been the most popular form of converting alternating current to a pulsating direct current from which the power supply units derive their energy. A vacuum tube loses its efficiency when the gas becomes ionized, when the tube has been paralyzed due to an excessive drain upon it, or, in the case of the thermionic type of tubes, when the filament burns out.

The Tungar bulb is a form of the thermionic rectifier but is not adapted to use of plate supply units. It is designed for use with low voltage and high amperage currents, such as battery chargers.

The half-wave and the full-wave thermionic rectifier tubes are used more extensively than any others. There seems to be no logical reason for the common adaptation of this type of tube for there are gaseous rectifiers that are as efficient as are those of the thermionic type.

Circuits for Power Units. The fundamental principle underlying all power unit circuits is identical. The difference in them is occasioned by the wide use to which they are to be put, the type of tubes used in the output stage of a receiving set, and the findings of the engineers with regard to the specifications of the chokes, transformers, capacities, and resistors.

B. H. Power Unit. The schematic diagram of a common form of power unit to furnish the plate supply to a receiver is shown in Fig. 13. This circuit uses the Raytheon BH tube, a gaseous rectifier having an output of 125 milliamperes. A power unit using this circuit will supply sufficient power to operate a set using a type 171 or 112 tube in the output stage. In this device the voltage divider circuit is arranged so that the detector and radio frequency voltages may be adjusted to meet the requirements.

The capacities used in the circuit are designated by *C-1*, *C-2*, *C-3*, *C-4*, *C-5*, *C-6*, and *C-7*. Condensers *C-1* and *C-2* should be

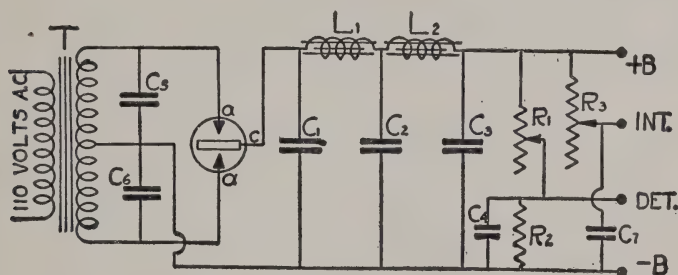


Fig. 13

capable of working under approximately 600 volts and should be 2 microfarads each. *C-3* is another high voltage condenser having a value of 8 microfarads. *C-4* and *C-7* are by-pass condensers of 1 microfarad each and may be of the lower rated type. *C-5* and *C-6* are what are known as buffer condensers connected between the outer terminals and center tap of the high voltage winding of the transformer. They need not have a capacity value of more than 0.1 microfarad but should be capable of withstanding a high working voltage. The values for the voltage divider resistors may be made in accordance with the instructions given previously.

Examination of the circuit will show that the center tap of the high voltage secondary winding becomes the negative side of the circuit. The action that takes place in an eliminator of this type differs from the one using the thermionic type of rectifiers. The center tap of the transformer can be easily visualized as the point of zero potential by observing the diagram shown in Fig. 20, which illustrates one cycle of alternating current. The

alternations carry through the windings of the transformer on each side of the center tap and are connected from the outer terminals of the transformer to the anodes of the rectifier tube. A power transformer provided with the secondary windings delivering the proper voltages could be used to supply the filament circuit for the receiver.

Thermionic Rectifier Circuit. There are two types of thermionic rectifiers for use in power supply units delivering high voltages such as those required in radio receiver and power amplifier circuits. One of the units is what is known as the half-wave rectifier, rectifying only one side of the alternating cycle. The other is known as the full-wave rectifier in that it takes both alternations of the cycle and rectifies them in the order in which they are furnished to the elements of the rectifying tubes.

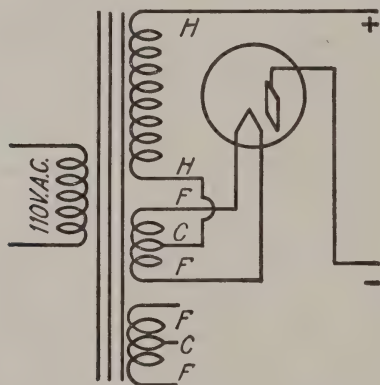


Fig. 14

The circuits used for gaseous rectifiers and thermionic rectifiers are identical in many respects. But there are points wherein they differ. The schematic diagram for a power circuit using the half-wave rectifier is shown in Fig. 14. A complete circuit is not shown since the filter and the voltage divider circuit for use with this unit is exactly the same as that used in the circuit using the gaseous rectifier. The rectifying portion of the circuit can thus be shown in more detail without confusing it with the elements of the circuit that are unnecessary in the rectification process.

The half-wave rectifier circuit consists of a power transformer and a rectifying tube of the 281 or 216-B type. The only differ-

ence between these two tubes is that the 281 has a greater output than the 216-B. The 216-B type is no longer available but many of the tubes are still in use. In case it is necessary to replace the 216-B, the 281 should be used.

There are two windings on the power transformer that are used in the rectification process, although there is usually another winding provided to supply the filament of a power tube used in a power amplifier circuit. Both filament windings are center tapped, but the high voltage winding is provided with terminals to the outside ends with no tap taken at the center. If a center tap is provided, it is disregarded. Alternating current is set up in all of the secondary windings, but in this instance we find a condition existing whereby both alternating and direct current are flowing through the same windings.

The heating of the filament of the rectifier tube causes the emission of electrons which are passed through the vacuum to the plate. The current flow in the tube is from the plate to the filament, however, so that by following the arrows it will be seen that the current is passed to the filament wire, is carried through the connecting wire to the end of the filament winding on the transformer, through a half of the filament winding to the center tap. At this point it leaves the filament winding and flows on through the high voltage winding where it is stepped up according to the ratio of the winding so that it emerges from the opposite end of the secondary winding with a voltage dependent upon the specification of the transformer. A low voltage rectified current could be provided if the secondary winding through which the current passed were made smaller.

The current continues from the transformer into the filter circuit, where it undergoes an ironing operation where the ripple is straightened out just as it is in the filter circuit of the eliminator using the gaseous rectifier.

A schematic diagram showing the connections for a circuit employing the full-wave rectifier is shown in Fig. 15. Here we have a rectifier of the thermionic type that rectifies both sides of the alternating wave. Instead of having a single plate as does the half-wave rectifier, the full-wave rectifier tube of the 213-B or 280 type has two plates. Here again it must be stated that the 213-B

is obsolete and the 280 has replaced it, the characteristics being identical with the exception of the current output.

The power transformer and the tube are the only requirements for the rectifier circuit of this power unit. The current passes from that part of the device into the standard type of filter composed of the chokes and condensers shown in Fig. 9, thence to the set through the voltage divider circuit shown in Fig. 12. The power

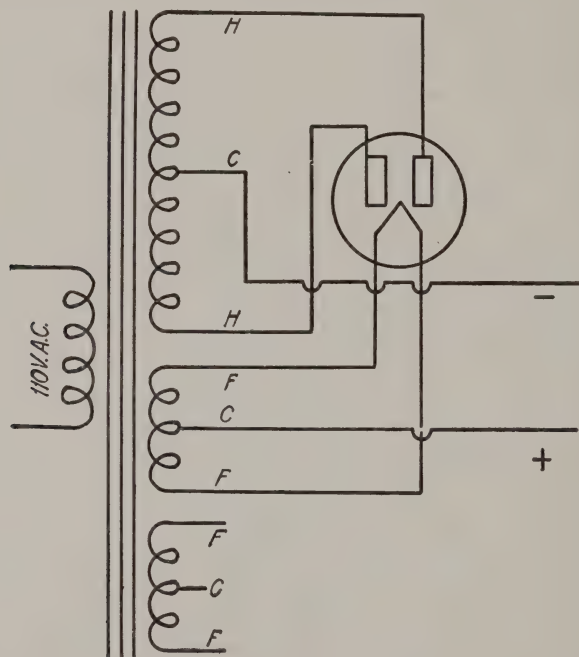


Fig. 15

transformer requires two windings—a low voltage secondary for the filament and a high voltage secondary for the plate current. The high voltage winding must be center tapped. The outer terminals of the high voltage winding are connected to respective plates of the rectifier tube and the outer terminals of the filament winding are connected to the filament terminals of the tube. The center tap of the high voltage winding becomes the negative side of the circuit while the center tap of the filament winding becomes the positive side of the circuit.

As in the case of the half-wave rectifier tube, when the filament is heated it emits a flow of electrons to the plates. The current flow is from the plates to the filament so that with one-half of the cycle the current flows from one of the plates to the filament, passes through the connecting wire to the filament winding and out at the center tap. When one side of the cycle has been rectified, the other side is flowing through the tube from the other plate and on through the filament wiring emerging at the center tap of the filament transformer so that both halves of the cycle are placed above the line, having been rectified and the lower alternation transposed, as shown in Fig. 8.

The action of the rectification process is easily understood if one will remember that the current flow through the rectifier tube is opposite to the flow of the electrons, that is, that the electrons are emitted by the filament and passed to the plate, but that the current flows from the plate to the filament. The center tap of the transformers represents a potential of zero so that that point has no effect upon the current in any way. If the center tap were off center where there would be a definite potential, the rectification process would be greatly hampered and the resulting current would be given an alternating characteristic that would greatly impair the rectification process by introducing a considerable portion of the other side of the alternating wave.

Power Packs. In Fig. 16 there is shown a schematic diagram for the construction of a power pack to supply the plate current for a standard type of receiver using a power tube of the 171 or 112 type and the full-wave rectifier of the 280 type. There is sufficient power available from this power unit to supply a receiver using the push-pull power stage.

The power transformer shown in the diagrams is so constructed that the filament circuits of the receiver may be supplied also. The transformer shown is designed to supply a receiver using the 226 type of tubes in the amplifier stages together with a single tube of the 227 type for a detector. The 5-volt winding shown supplies the power tube or tubes, the transformers being usually designed so that two of the 5-volt tubes can be supplied without overloading the winding.

When tubes of the 210 type are used in the power stage of the

receiver or for a separate power amplifier, it is necessary to use the half-wave rectifier tubes for rectification. Fig. 17 shows a diagram of the power pack to supply the plate current for the receiver equipped with a 210 amplifier. In this circuit also we find the power transformer provided with the secondary voltages to supply the filament circuits for the receiver.

When two tubes of the 210 type are used in parallel or push-pull, a still greater rectified output will be necessary. Fig. 18 shows

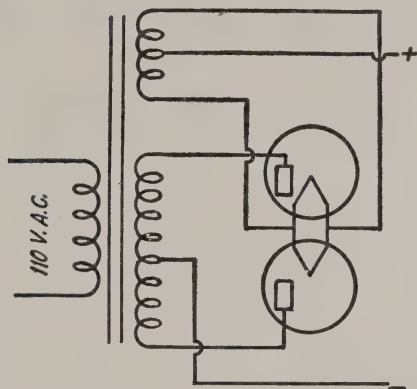


Fig. 18

the rectifier circuit for a power unit to supply sufficient current to supply an amplifier using the two tubes of the 210 type or a single tube of the 250 type using the filter circuit shown in Fig. 18. It will be noted that the circuit is a combination of those shown in Fig. 16 and Fig. 17.

Physical Specifications for Transformers and Chokes in Power Units. Specifications for transformers can be given only in the approximate. The actual calibration of transformer units is dependent upon several unknown quantities, among which is the permeability of the iron used in the core. In the factories there is special apparatus to determine the variable elements so that they can conduct their experiments and arrive at a definite conclusion without delay. Anyone preparing to construct transformers should equip themselves with meters in order to determine the characteristics of the units which they build. It is hardly likely that the first attempt will develop a power transformer that will give

the correct values, but from the first unit it will be possible to determine nearer the correct figures.

The core of a power transformer should be built up of thin sheets of steel. Silicon steel is usually found to be the best suited for home laboratory construction. The laminations are dovetailed together so that they form an apparent solid path for the magnetic field.

There are several types of transformer cores, but the one best adapted to power transformer construction is known as the shell type, the shape of which is shown in Fig. 19. Using a core of this

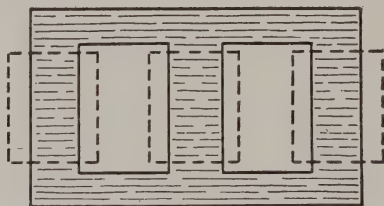


Fig. 19

type, the primary winding can be placed upon the center bar with a secondary winding split, one-half being placed upon each of the outer bars as indicated by the dotted lines. It is not necessary that that procedure be followed, however, for all windings can be placed upon the center bar, as the outside bars serve merely as an outside path for the magnetic field.

The thickness of the core depends upon the amount of energy to be dissipated. The approximate sizes of cores used with transformers in the various power packs that have been described are given in the following paragraphs.

The Raytheon BH tube is a full-wave rectifier of the gaseous type with an allowable supply to each of the cathodes of 350 volts. It is not the best policy to deliver the maximum voltage to the electrodes, and for that reason a transformer designed to deliver 600 volts over the entire secondary winding—300 volts each side of the center tap—will be satisfactory.

Such a transformer would be placed upon a core approximately $1\frac{1}{4}$ inches in cross-sectional area. There should be 600 turns of

No. 20 enameled wire wound as closely as possible for the primary winding. Analyzing the primary winding, it will be seen that there are 5 turns per volt of line supply, taking a mean value of the voltage supplied on the lines, or 120 volts.

The secondary winding should be wound of No. 28 or No. 30 enameled wire, and 3600 turns would be required to furnish 600 volts. Since there must be a center tap, it is recommended that two coils of 1800 turns each be wound simultaneously. If it is desired to place a winding on the transformer to supply the filament of the 171 of the 112 type tube, use 28 turns of No. 20 or No. 22 enameled wire.

The transformer for use with the type 280 rectifier tube follows very closely the specifications for the unit to be used with the BH tube. The size of the core and the primary and filament windings are the same except that the filament winding to supply the 280 tube should be wound with No. 16 enameled wire. The specifications for the tube as given by the manufacturers show that a maximum of 300 volts should be delivered to the plates of the tube. Hence we reduce the number of windings on the secondary, placing 3000 turns of No. 28 or No. 30 enameled wire. The winding for the 1.5 supply should have 8 turns of No. 12 enameled wire and the 2.5 winding should have 13 turns of No. 12 enameled wire.

A transformer to operate with the power pack to supply a receiver using a single 210 type tube should be built with a $2\frac{3}{4}$ -inch core. The primary winding should have 300 turns of No. 18 or No. 20 enameled wire. The 281 tube requires a filament voltage of 7.5 volts, so that there should be 23 turns of No. 16 enameled wire. The secondary winding should have 3000 turns of No. 28 enameled wire. The winding to supply the 1.5 volts to the 226 type tubes should have 4 turns of No. 12 enameled wire, while the winding for the 2.5 volt supply should have 7 turns of No. 12 enameled wire.

So far as the chokes are concerned, it is necessary that they be of high inductance and at the same time have a comparatively low resistance. A choke of twenty or thirty henries is usually recommended. A square type of core is used in choke construction, but it is not closed entirely, a gap known as the air gap being provided at one or more points in the core construction. The core

for the choke coil should be built of lamirations just as the core for the power transformers.

The inductance of the choke being known, it is easy to find the number of turns to be used in the unit. A practical formula that will suffice for calculations of filter chokes shows that the inductance is equal to the core area in square inches multiplied by the square of the number of turns, the product divided by the size of the air gap in inches multiplied by 40,000,000. The resistance of the unit must be taken into consideration to determine the proper size of wire to be used.

As an example, the chokes for use in the power unit using the BH tube should have a resistance of not more than 350 ohms each, a total of 700 ohms. Each choke should have an inductance of 30 henries. We shall estimate the air gap at .025 of an inch and the core will be 1 inch square. Hence we have

$$30 = \frac{1 \times (\text{Number of turns})^2}{.025 \times 40,000,000}$$

Calculating the equation, we find that 5476 turns of wire will be required. Now to determine the size of wire, estimate the average length of each turn of wire, and on a 1-inch core in a choke of this type it is safe to say that the average side of the coil will be about $1\frac{1}{8}$ inches or $4\frac{1}{2}$ inches for each turn of wire. Dividing 4.5 by 12, it is found that $4\frac{1}{2}$ inches is $\frac{3}{8}$ of a foot. We find $\frac{3}{8}$ of 5476 is 2053.5, the actual length of wire in feet that will be used in the coil. Reference to a table giving the resistance of copper wire shows that No. 32 wire has a resistance of 164 ohms per 1000 feet, so that No. 32 wire is the correct size to use. The current to be dissipated through the coil is comparatively light, so that a choke coil wound on a 1-inch core with 5500 turns of No. 32 enameled wire would serve the purpose.

The choke coils for use with the larger types of power units will necessarily be larger. The choke should be constructed of wire large enough to carry the current which will pass through it without overheating the coil. The values for the choke coils in the other power packs can be worked out from the formula given above together with the illustration and a table showing the wire resistance and current-carrying capacities of wire.

TYPES OF A. C. SETS

Alternating-current sets were received by a skeptical public. Manufacturers of sets had the idea that it was only necessary to replace the direct-current tubes with those of the new type, insert the necessary resistors, and provide a transformer that would give an approximate secondary supply, further controlling the voltage delivered to the tube filaments by means of a variable resistance installed either in the set or as an external control on the primary of the power transformer.

The transformer manufacturers had learned from the experience of the experimenters and set manufacturers that the voltages as provided by the first run of filament transformers were too high. It was found that while the straight filament type of tube, UX-226, was a tube for 1.5 volts, it would work efficiently on a supply as low as .95 of a volt. Similarly, the heater type tube, UY-227, carrying the specifications of 2.5 volts on the filament, was found to work on a supply of 1.95 volts. The result has been that, without going to the low level, the manufacturers have provided units that deliver to the tube filaments 1.4 volts for the UX-226 tube and 2.3 volts for the UY-227 tube, the value of the secondary voltage being based on a 125-volt line current.

There are several types of alternating-current sets and there are those which are said to be alternating-current sets that are in reality direct-current sets equipped with power units so that they appear to be operating directly from the light lines.

While an alternating-current receiver is considered to be one which uses the alternating-current tubes, it is not essential that that be the case. Stromberg-Carlson Manufacturing Company and Federal Electric Company have placed on the market alternating-current sets equipped with a rectifier outfit that delivers direct current to the filaments of the direct-current tubes, the filaments being wired in series so that a higher voltage and lower amperage would be required. Wired in this manner, the tubes drew only a quarter of an ampere, but the voltage was the sum of the voltages required for each individual tube. Thus, if seven of the five-volt tubes were used, it would be necessary to supply thirty-five volts to the filament circuit.

Another method by which the direct-current tubes may be used in an alternating-current set is found in the Symphon, a new product of the Fansteel Products Company. It uses the output of a type 210 tube acting as an oscillator to supply a current having a frequency of approximately 3,000,000 cycles per second to the filaments of five tubes of the 201-A type.

The more popular circuit, however, is that which uses the alternating-current tubes—the UX-226 and the UY-227. The UX-226 is of the straight filament type while the UY-227 is so arranged that the alternating current does not enter the circuit but serves as a heating element for the cathode which is coated with an oxide that emits the necessary electrons when heat is applied. The heater type of tube was originally designed for use as a detector, but some of the manufacturers have adopted it for use in the amplifier stages as well, due to the fact that the alternating current is kept out of the circuit and therefore the elimination of hum due to the presence of the sixty-cycle alternating current is made easier. The heater type of tube is especially adaptable for use in the home-made sets where laboratories are not available to balance the circuit to remove carefully any residual hum that might arise from the use of the straight filament type of tubes.

In constructing the sets using the alternating-current tubes there are a few points that should be kept in mind. First of all, the alternating-current tubes are of the low voltage, high current type. This fact calls for a provision for the carrying of larger currents than was necessary when the direct-current tubes were used, necessitating the use of heavier wire for the filament circuit.

Secondly, there must be some method of completing the grid circuit so that there will be a return not only for the grid but the plate as well. Since there is no positive or negative to the alternating current, it is evident that some other means must be provided. Fig. 20 shows a simple curve indicating one cycle of alternating current. At the upper dotted line there is what is considered to be the maximum positive potential obtained from the generator or transformer winding. Similarly, the lower dotted line designates the maximum negative potential. A voltmeter connected across the line measures the difference in potential between the points indicated by the dotted lines. If a resistor unit is connected

between the alternating-current lines and a tap is taken at the exact center, a zero potential indicated by the line at "O" results. Another way of obtaining the result is to take a tap at the center of a secondary winding. A voltmeter reading between the center tap of a resistor or tapped winding and either of the outer terminals will be found to be half that obtained across the entire winding. Grid biases as well as the returns for the plate and grid circuits of the radio receiver are obtained from the zero potential point of the alternating circuit.

In order that the tap on the secondary of a transformer may be in the exact center, the transformer should be made of two coils wound simultaneously so that the number of windings will be

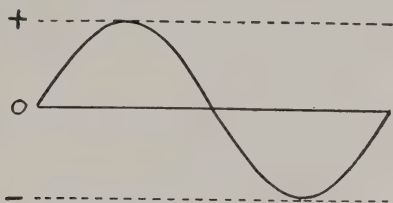


Fig. 20

exactly the same. It has been customary for some of the transformer manufacturers to wind on half the windings, take out the tap, and continue with the second half. Discrepancies are likely to occur when this method of construction is used.

The receiver and the power unit were separated in the first models of alternating-current sets that came on the market. This procedure was followed to eliminate the magnetic coupling that would naturally enter into the circuit if the two units were placed in close proximity. But the research laboratories managed to successfully shield out the magnetic coupling so that now practically all the manufactured receivers are mounted on a single chassis, the power unit being thoroughly shielded from the tuning portion of the set.

Four sets to be described are representative of the sets of today. Two sets that employ the straight filament type of tubes are shown, one being a receiver that combines the tuning circuit and the power unit on a single chassis, the other being made in two separate parts with the power unit designed for use with an electro-

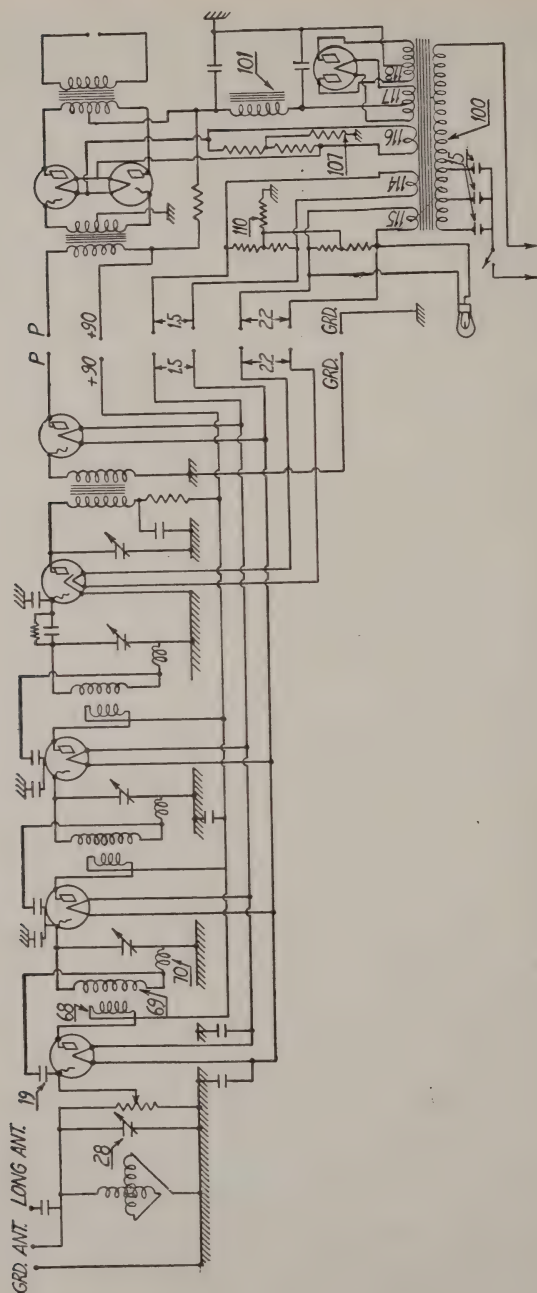


Fig. 21

dynamic speaker. The third set uses the heater type of tubes throughout the amplifier stages as well as the detector. The fourth set is one of the custom-built variety and it not only is a super-heterodyne circuit but embodies the shield grid tubes as well.

The Bosch "28." Following the schematic diagram of the Bosch "28" shown in Fig. 21, it is seen that the circuit is that of a neutrodyne using the straight filament type of tubes in the amplifier stages with a heater type of tube as a detector and a push-pull stage of audio amplification using the type 171-A tubes in the output.

NOTE: The information that is given on the Bosch set will apply to other similar circuits, the only difference being the location of individual parts of the set. While the system of neutralization used in this circuit may differ from that used in other sets, the principle is the same in all alternating-current sets no matter what the receiver may be.

Although the apparatus is included on the same chassis, the Bosch is divided into two separate and distinct units, the tuning

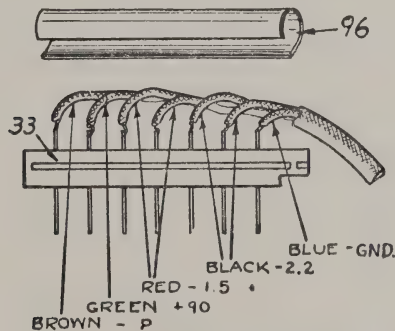


Fig. 22

unit and the amplifier. The two sections are connected by a cable and connector shown in diagram in Fig. 22 and at 33 in Fig. 24.

Beginning at the antenna stage, the first point is to follow through the wiring of the antenna circuit. The variometer which is connected across the antenna and ground, controlled by knob 1 in Fig. 24, is for use in adapting the receiver to the antenna that is used. The variation of the inductance in the antenna circuit permits placing the input circuit in resonance with the other tuning stages. Actually, the antenna should be so arranged that the reson-

ant point will be found approximately at the center of the swing of the variometer. In tuning, the variometer also serves as a means for separating stations by detuning the antenna circuit.

The variable condenser, 28, is shunted across the outer terminals of the variometer for the purpose of tuning the inductance. Due to the fact that the value of the inductance can be varied, the condenser in the antenna stage is mounted on the shaft with the three remaining tuning condensers and operated simultaneously with them.

A potentiometer connected across the stator and the rotor of the condenser serves as the volume control for the receiver. The outer terminals of the potentiometer are connected across the condenser so that it is really across the variometer and between the antenna and the ground. The arm of the potentiometer is connected to the grid of the first tube and the signal that is impressed upon that grid is the one that is amplified through the successive stages. In the alternating-current receivers, the volume control has been found to act more readily when placed in the antenna circuit rather than to wait until the signal has been amplified and then reduce it.

The method of controlling the volume of the alternating-current receivers is similar to that employed in the amplifiers used for public address systems. In effect it controls the modulation of the signal and aids greatly in the clarifying process by introducing the proper amount of resistance in the circuit to adjust the impedance of the first stage.

An analysis of one of the radio frequency stages will suffice for the entire tuning unit since the others are duplicates. The circuit is that of a neutrodyne, but the neutralizing process is carried out slightly different from that in common use. The radio frequency transformers consist of three windings—the primary, the secondary, and the tertiary. The construction of the unit is shown in Fig. 23. The numbers on the cut are reference numbers for use of Bosch service men.

The primary coil 68 serves in the capacity of a plate coil and receives the impulses from the plate of the vacuum tube. The impulses passing through the windings are transferred to the secondary coil 69 by induction. The primary and the secondary coils

are thus inductively coupled and the frequency of the current flowing through the secondary coil is exactly the same as that of the current passing through the primary coil. Then there is a third coil 70, known as the tertiary, whose purpose is to add the proper amount of inductance to the secondary or grid circuit and at the

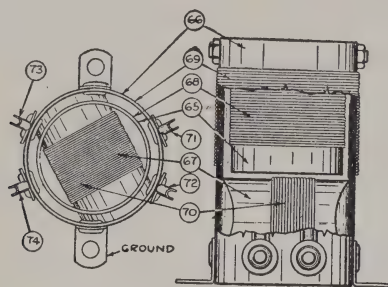


Fig. 23

same time not be in an inductive relation to the plate coil. It is mounted inside the secondary coil and is arranged so that it is at right angles to both the primary and the secondary windings, thus cutting down the effect of the magnetic fields.

One end of the secondary coil is connected to one end of the tertiary coil, and from this junction a connection is made to the neutralizing condenser 19, from the other terminal of which a connection is made to the grid of the preceding tube.

An electrostatic shield is provided for each radio frequency transformer to prevent coupling between individual stages. The use of the shield permits of the construction of the set in a comparatively small space. However, due to the presence of the shield, it is necessary to provide a greater number of windings on the tuning coils to give the proper amount of inductance for the condensers used.

The plate coil is wound on a bakelite tube, having a diameter small enough to allow it to fit inside the tube upon which the secondary coil is wound. On the base for the primary coil there is placed 20 turns of nichrome wire which has a resistance of approximately 300 ohms. The large number of turns of wire permits of the transfer of a large amount of energy and at the same time the

high resistance of the winding itself provides a higher impedance to match the output impedance of the tube.

The secondary coil contains 83 turns and the tertiary coil 50 turns of No. 30 enameled copper wire. There is a total of 133 turns of wire to give the proper amount of inductance to be tuned with the .00035 microfarad condensers as against approximately 75 that would be required were it not for the shields surrounding the coils. The wire used for the secondary coils must have a minimum of resistance, for if resistance is introduced in the tuning section of the tuner, the circuit will be broad in tuning—a condition that would be very undesirable under present-day conditions.

The effect produced in the neutralizing section of the stage is identical with that of a tapped secondary where the tap was formerly taken from a position a few turns removed from the grid return or low potential end of the coil. The purpose of the neutralizing is to balance out the capacity between the plate and the grid of the vacuum tube and thereby prevent the backward flow of oscillating currents. The balancing may be effected by connecting directly across the elements, but the results are not so good as when the circuit includes at least a portion of the inductance. In order to make the neutralizing more effective, the oscillations may be stopped in the grid coil of the succeeding stage where they originate. The oscillating current can then be damped out at the source rather than wait until it has gathered momentum and been accentuated by the inductance in the plate circuit as well as the grid circuit.

The detector circuit is wired in the conventional manner. The cathode of the heater type of tube is connected to the chassis of the receiver which in turn is grounded so that the cathode of the detector tube is said to be at ground potential. The bias for the grid of the detector tube is obtained through resistors in the power unit. The wiring of the tuning section of the Bosch set is shown in Fig. 26.

The first audio stage is made an integral part of the tuning device, a procedure that is found in the majority of the present receivers. Straight transformer coupling is employed in the first stage of audio amplification. The negative grid bias is obtained through resistors as shown in the diagram.

Seven terminals are brought out on a cable, as shown in Fig. 22.

The designations for the individual wires are shown in the schematic diagram, Fig. 21, while the pictorial layout, Fig. 24, shows where they appear on the unit at 33.

The power unit, shown schematically in Fig. 21 and pictorially in Fig. 25, uses a rectifier tube of the 280 type, it being a full wave

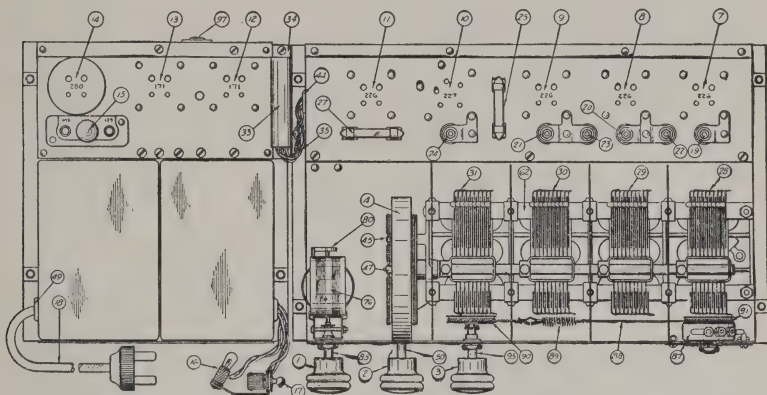


Fig. 24

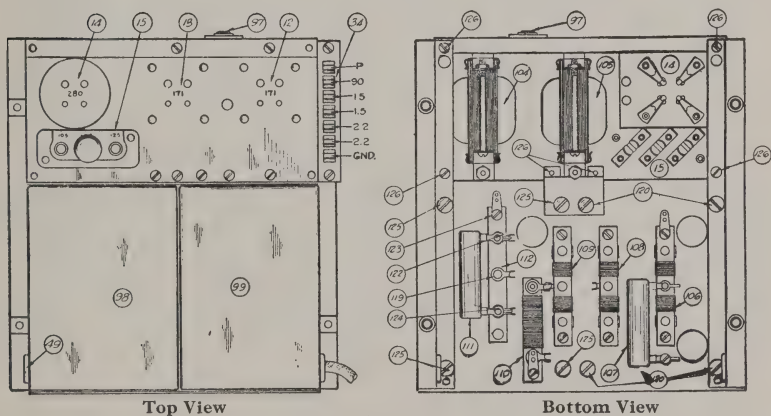


Fig. 25

rectifier for use with tubes of the 171 type. Sufficient power is obtained to furnish the plate current for the remaining stages of the receiver.

The 171-A type tubes for the push-pull stage of audio amplification are included in the assembly for the power unit together with the input and output transformers required for the stage.

Referring to the schematic diagram, Fig. 21, the power transformer will be found at 100 while the filter choke is seen at 101. The openings in the primary circuit of the transformer at 15 are not condensers as they may appear, but are jacks to receive a plug

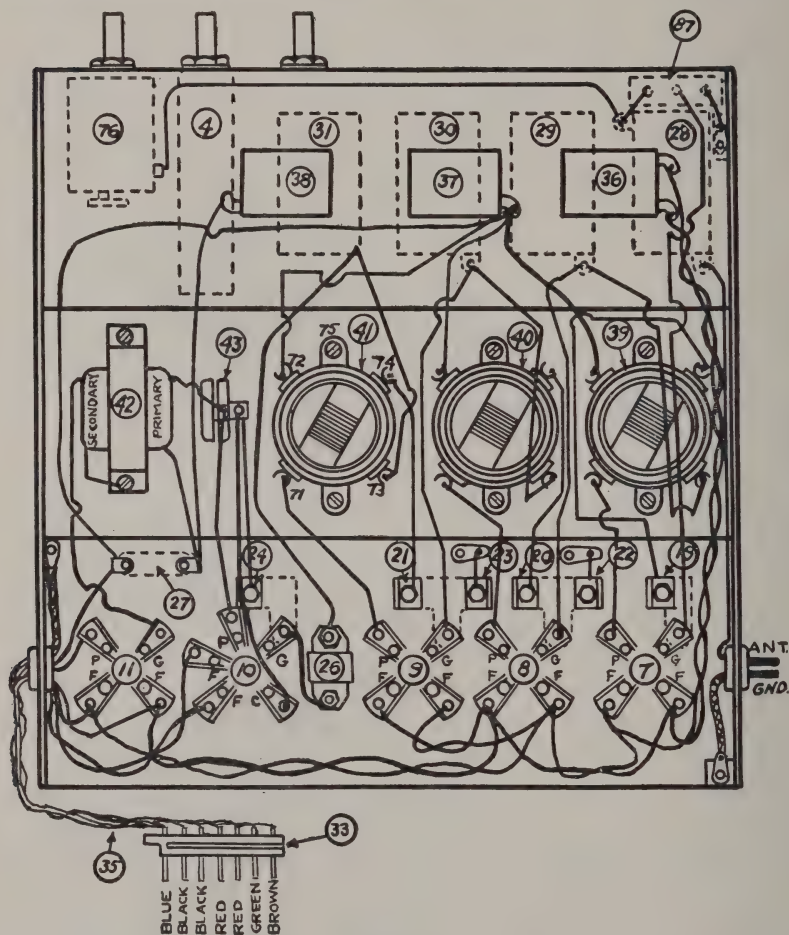


Fig. 26

which adapts the transformer to different line voltages. This plug will be found at 15 on the pictorial layout of the chassis. The grid bias resistors are shown at 107 and 110, the former providing the bias for the power tubes and the latter providing a 5-volt bias for the first stage of audio and the radio frequency stages.

There are five secondary windings on the power transformer. At 114 is a winding to furnish the filament supply for the 226 type tubes. At 115 is the 2.2-volt winding for the detector tube and the pilot light. Winding 116 provides the 5-volt supply for the 171-A tubes in the push-pull stage. At 117 is another winding to furnish the supply to the filament of the rectifier tube. Winding 118 is the high voltage winding to connect to the plate elements of the rectifier tube from which the high plate voltages are obtained.

Windings 117 and 118 are center tapped, the former to provide the positive side of the direct-current line while the latter is the negative B, from which point the grid biases and ground potentials are determined. All connections made to ground shall be considered as though they were connected by a wire. Modern sets use the shield or chassis as the common connection for all ground potentials.

Center tapped resistors are provided for the pairs of wires carrying the current to the filaments of the tubes in the tuning unit as well as the amplifier. The purpose of these resistors is largely to eliminate the alternating-current hum that would be occasioned by the passage of the sixty-cycle current through the receiver connections. In addition they serve to provide the zero point from which the grid voltages are obtained in their relationship to the negative side of the plate current.

Instead of using a voltage divider circuit across the output of the plate supply unit, the various voltages are secured by means of series resistors. This circuit is permissible in a complete unit such as the Bosch where the power switch simultaneously turns off all circuits of the set and does not permit a backward surge of current such as would take place if the filament were turned off in advance of the power supply circuit. The power switch is connected in the primary of the power transformer, which means that all current supply is shut off at the source.

In the late Bosch 28 sets, provision was made so that an alternating-current electrodynamic speaker could be plugged into a receptacle provided at the rear of the chassis. By means of this connection the alternating-current supply to the speaker was disconnected at the same time that the set was turned off, eliminating the necessity of turning off the speaker at the switch in the extension cord.

The Majestic Model "70." The Majestic receiver, which is very popular in the radio world, is similar to the Bosch. Their points of difference are that the receiver and the power unit of the Majestic are divided and the antenna coupling stage is arranged in a different way.

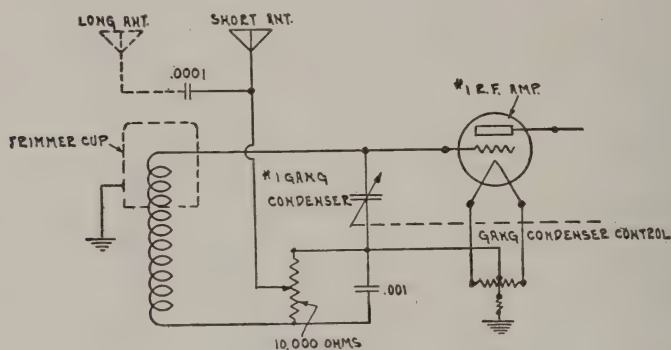


Fig. 27

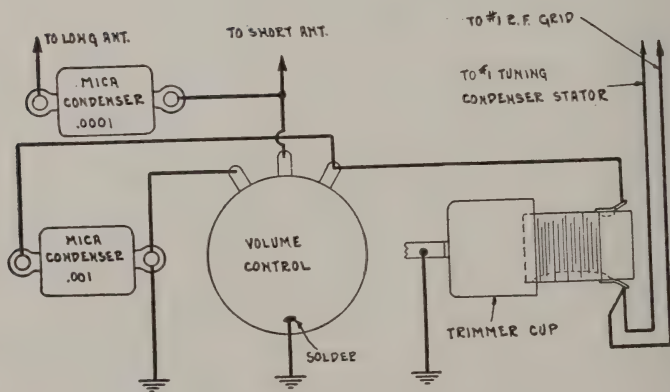
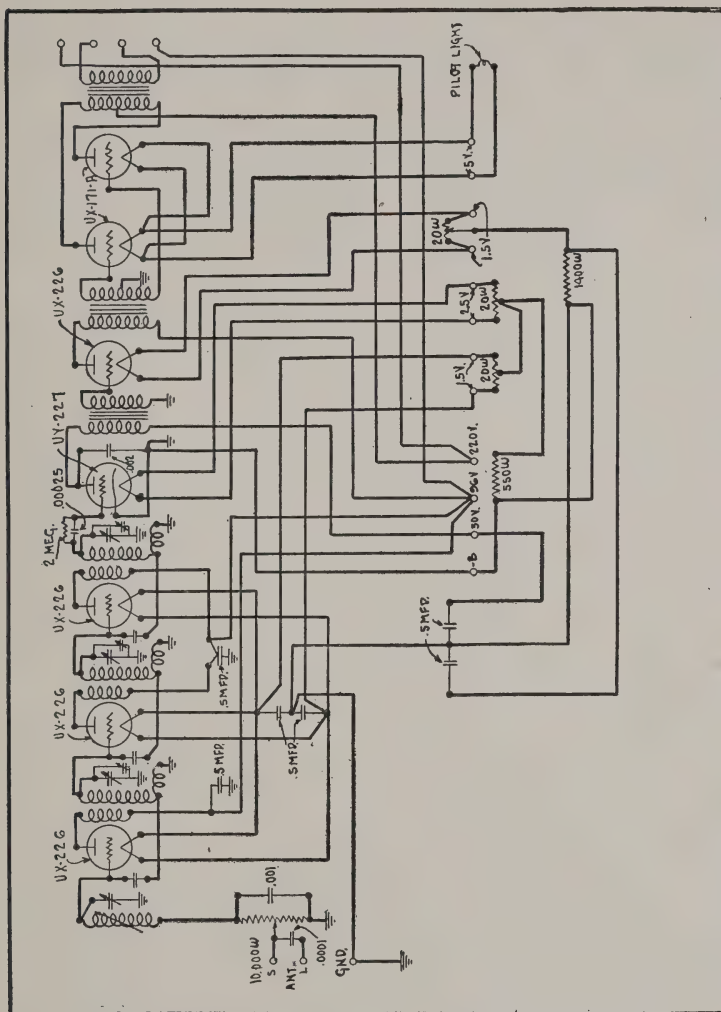


Fig. 28

The antenna coupling stage can be seen schematically in Fig. 27, and pictorially in Fig. 28. A 10,000-ohm potentiometer is connected between the ground and one end of the antenna inductance. A .001 microfarad condenser is shunted across the terminals of the potentiometer to serve as a by-pass for the radio frequency currents and to reduce the over-all impedance of the circuit. The



arm of the potentiometer is connected to the antenna post, so that the intensity of the signal is varied according to the amount of resistance that is placed between the antenna and ground. As the resistance is increased or the arm brought nearer the end of the resistor that is nearest the inductance, the signal will pass through the inductance more readily and the volume will naturally take a higher level.

A glance at the antenna inductance in the schematic diagram shown in Fig. 29 will show that unit to be variable. On looking at the coil in the set, however, it will be seen that it is a solenoid coil and that the windings have a definitely fixed relation. But a metallic cup, called a trimmer cup, is mounted on a rack in such a manner that it will slide over the end of the inductance and form an electrostatic shield around the windings over which it is passed. By means of this arrangement, the antenna circuit can be brought into resonance with the remainder of the circuit.

Further investigation of the schematic diagram of the Majestic receiver shows that there are four terminals at the right of the output transformer. The top and the bottom of those terminals are required to supply the field current for the electrodynamic speaker designed to operate with the Majestic set. The upper terminal has a value of 220 volts positive while the lower one is common with the 96-volt tap of the power unit from which the radio frequency and first audio frequency tubes are supplied. The field winding of the speaker causes a voltage drop of 124 volts, which is the equivalent of approximately 3,100 ohms since the current draw for the speaker is about 40 milliamperes.

Fig. 30 shows the filament wiring for the set with tuning units removed. There are two 1.5-volt filament sources provided. Following through the circuit it will be seen that the winding on the right supplies the first audio tube while the one on the left connects with the first three tubes of the set in the radio frequency stages. By connecting from the center tap of the resistor across the filament terminals of the first audio tube through a 1400-ohm resistor, a bias of 5 volts is placed on the grid of the first audio tube by making the filament positive in its relationship with the ground or by making the ground at a lower potential than the filament. This value is obtained by dividing 5, the desired grid

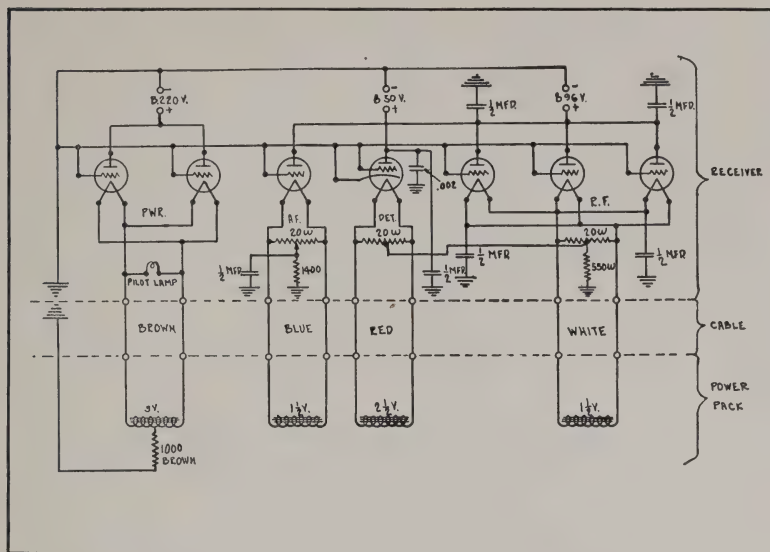


Fig. 30

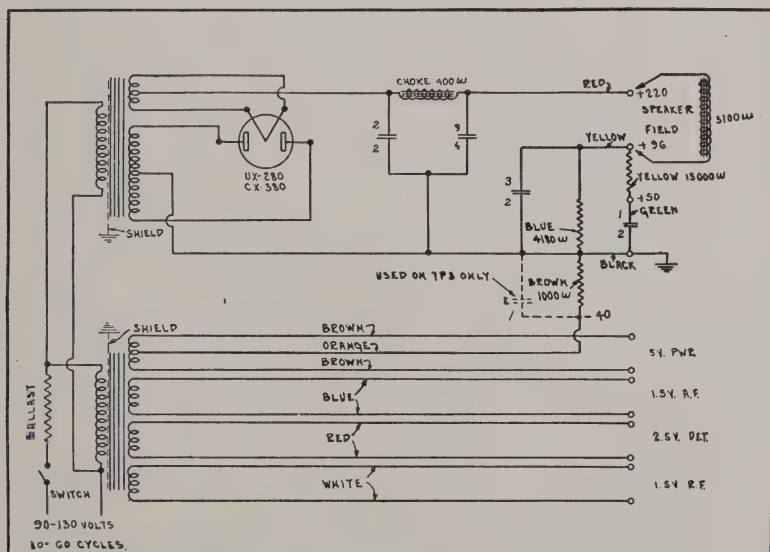


Fig. 31

bias, by .0035, the plate current drawn by the single tube. Ohm's law is used in making the calculation.

Similarly, we find that a 550-ohm resistor between the center tap resistor across the radio frequency filament supply gives a bias of about 4 volts to the radio frequency tubes.

Fig. 31 shows the schematic diagram of the power pack that is designed for operation with the Majestic receiver. Two values for each of the condensers are shown. The upper value at each capacity unit designates the capacity in microfarads for the unit to be used with a 60-cycle pack, while the lower value represents the capacity to be used for the unit designed to operate on 30-cycle alternating current.

The negative bias for the 171-A tubes in the power stage is provided by the 1000-ohm resistor immediately below the ground. Each of the tubes drawing 20 milliamperes shows that a 40-volt bias is provided for the tubes.

The speaker field winding is designated by the 3100-ohm inductance at the upper right corner of the illustration. To the left of the filament transformer there is a unit marked "ballast." This unit is for protection of tubes and prevents disastrous increases in the voltage applied to the tube filaments because of increases in the line voltage. The primary supply to the transformer is dropped several volts through the ballast resistor so that more turns can be used on the secondary windings, thereby insuring better control of the secondary voltages.

The layout of the power unit is shown in Fig. 32. At the upper left-hand corner the terminal strip is detailed to conform to the connections on the terminals of the power pack. The value of each of the terminals may be noted by referring to the terminals shown in the illustration. Terminal *A* is the negative terminal and is offset to prevent placing the terminal strip in position incorrectly.

Fig. 33 shows the receiver chassis as it is seen from the top and out of the cabinet. The radio frequency portion of the circuit is located at the left end of the chassis while the power circuit is placed at the right end. The elongated shield at the lower right-hand corner of the construction is the gang of tuning condensers. Each of the audio transformers is individually shielded at the left

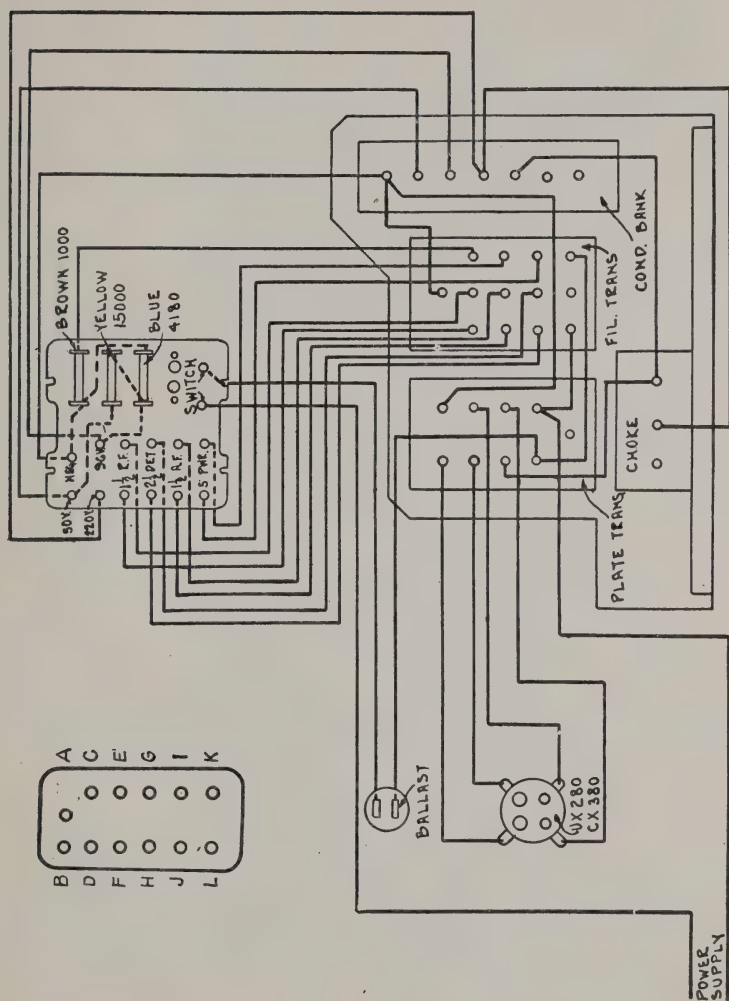


Fig. 32

end of the chassis. The layout of the under side of the chassis is shown in Fig. 34. Notice that the radio frequency transformers are individually shielded. This diagram shows the location of practically all the points that would require testing in the receiver.

The Stromberg-Carlson "635." The Stromberg-Carlson receiver makes use of the heater type of tubes throughout all the amplifier stages. It, too, is of the neutrodyne type, using the conventional Hazeltine type of neutralization where the neutralizing is effected through a tapped grid coil.

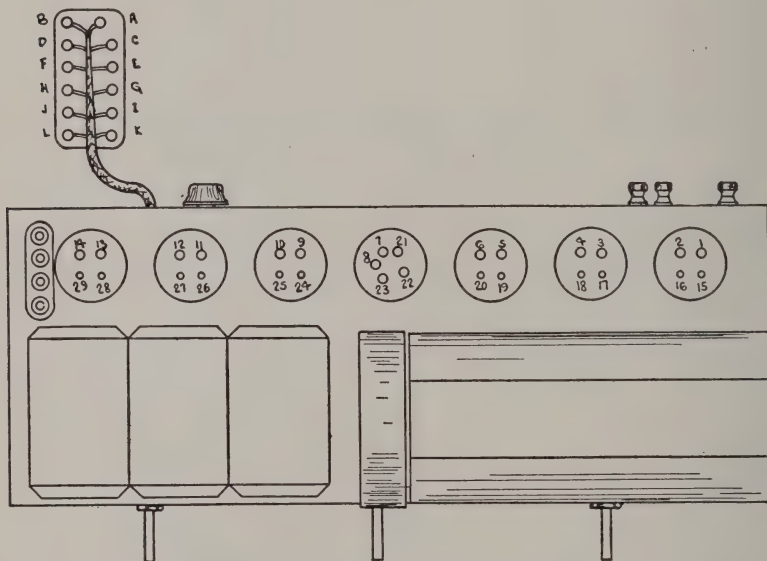


Fig. 33

The schematic diagram of the Stromberg set is shown in Fig. 35. The power unit is incorporated as an integral part of the chassis and is shown together with the receiver in the diagram. There are several special features in the construction of this receiver.

The volume control designed by the Stromberg engineers is different from that used on other sets. It consists of two resistors—one a 10,000-ohm rheostat and the other a 10,000-ohm potentiometer, as shown in the diagram at Fig. 36. Although controlled by the same dial the rheostat and potentiometer are insulated from each other by a bakelite rod. The potentiometer is connected across

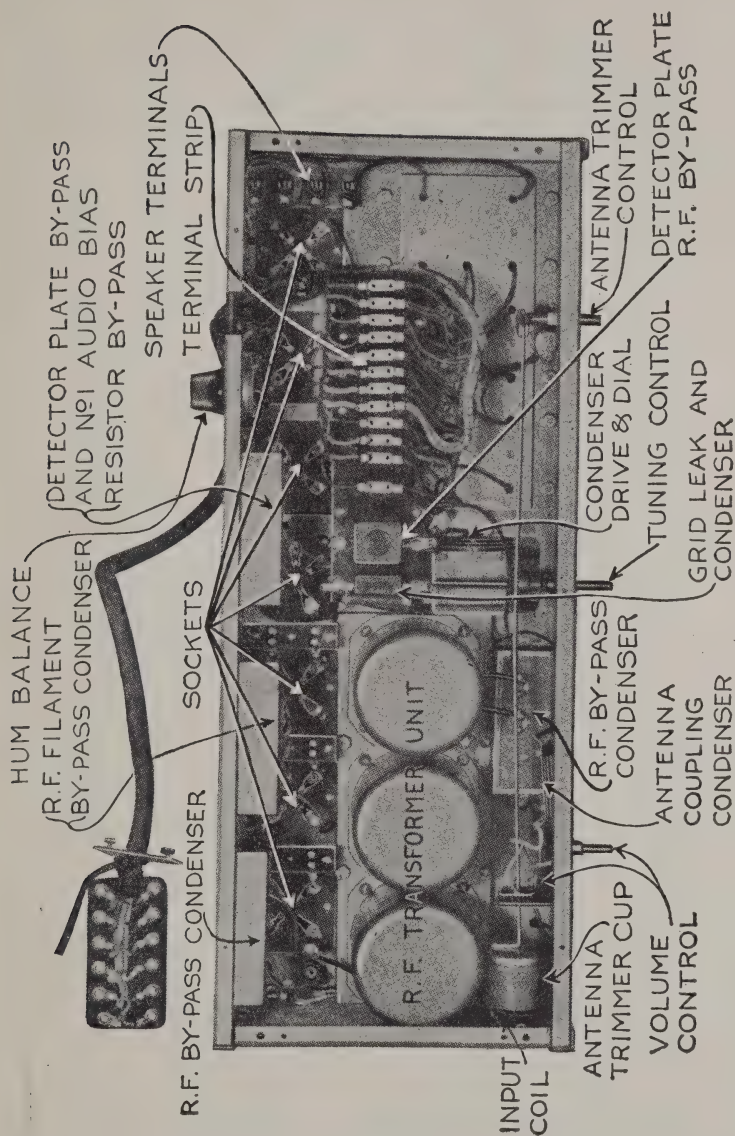


Fig. 34

the antenna inductance with the arm of the unit connected to the ground binding post. The action at this point is identical with that of the other sets described. After the signal has passed through the radio frequency amplifier, it is again subjected to a volume control that is operated simultaneously with that in the antenna stage. The second unit is the rheostat connected across the primary coil of the radio frequency transformer in the detector stage. By using the resistance at this point, the intensity of the signal that is im-

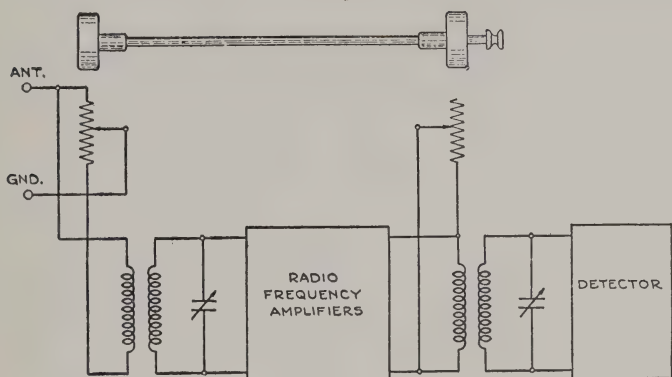


Fig. 36

pressed upon the grid of the detector tube is materially lessened and the possibility of overloading the detector tube is made more remote.

The grid bias voltages are provided by means of voltage-drop resistors between the cathode and the ground or grid return end of the radio frequency transformers. By placing a 1500-ohm resistor in the cathode lead, a 5-volt bias is provided on the grid of the tube and such an arrangement is found in the radio frequency and the first audio stages. The bias for the power tube is obtained by means of a 770-ohm resistor in the voltage divider circuit of the power unit.

Here, too, the values of the grid resistors are obtained by using the formula $E = IR$. It is desired to obtain a grid bias of 5 volts and the current draw is approximately .0035 of an ampere. The calculation will show that a value of more than 1400 ohms will be necessary, and since the 1500-ohm resistor will not change the

voltage value perceptibly, that value is used in preference to a resistor with an odd ohmic value.

When the Stromberg-Carlson receiver was designed, the plate rectification system of detection was used, but it was abandoned due to the fact that the grid condenser method shown in the diagram increases the sensitivity of the set. It seems best to describe plate rectification, however, in order that its application to the circuit may be known and be of service in case it is necessary to service a Stromberg set in which the detector circuit is not of the later type.

Fig. 37 shows the schematic connections for the plate rectification system in the Stromberg set. Notice that the grid condenser

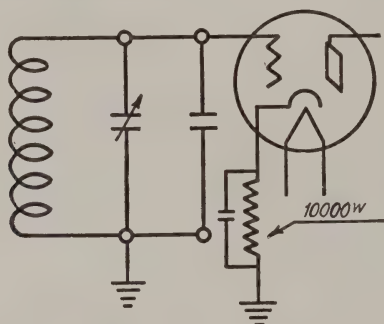


Fig. 37

and grid leak are eliminated. In the standard circuit the grid condenser serves to break up the radio frequency impulses into a series of wave trains, the charges upon the plates acting to damp or retard the flow of the alternating impulses flowing through the circuit. The grid leak acts as a means to allow the excess electrons on the grid to flow back to the filament circuit.

A negative bias is required on the grid of the detector tube when plate rectification is used. The value of the grid bias should not be as high as that provided for the amplifier stages, however, 3.5 volts being considered an efficient value. As the radio frequency impulse comes through the radio frequency amplifier it is an alternating current, so that the grid of each tube is alternately charged negatively and positively unless changed by means of an outside source. If the charge upon the grid is made negative, the negative impulses are accentuated while the positive charges are neutral-

ized, with the result that the impulses are placed above the line of zero potential, or nearly so. The small portion remaining on the negative side of the zero line will be of little consequence and will be ironed out through the tube action. In calculating the value of the grid resistor for plate rectification, take into account the lower plate current on the detector tube. It will approximate .0005 of an ampere.

The Stromberg set includes another feature which has not been shown in either the Bosch or the Majestic—the phonograph pick-up jack. A double circuit jack is used for the purpose and is connected so that on inserting a radio plug on the pick-up leads the connection between the plate of the detector tube and the first audio transformer is broken as well as that between the detector plate voltage supply, which, in the Stromberg set is 36 volts, and the primary of the first audio transformer. The output of the electric phonograph pick-up unit is connected between the detector plate voltage and the primary of the first audio transformer so that the 36 volts serve to actuate the impulses that are given off by the pick-up and give them force enough to be effective on the audio system.

The Tyrman Imperial "80." In the Tyrman "80" we find not only the superheterodyne circuit, but also have the opportunity of investigating the use of the shield grid tube. The schematic diagram shown in Fig. 38 differs from the customary diagram in that it shows the position of the parts on the chassis and the wiring between the units approximately as it should be placed, the only deviation being found in the filament wiring, a part of which should be twisted.

Tubes of the heater type are used throughout the entire set with the exception of the last audio stage where one of the 250 type of tubes is placed. The power tube is included in the assembly of the power unit, however, and does not appear on the diagram showing the circuit of the set.

In order that the circuit may be better understood another schematic diagram is shown in Fig. 39. From this diagram a better analysis of the circuit may be made. The schematic diagram of the power unit also appears in Fig. 39.

The power unit was originally mounted on the rear of the

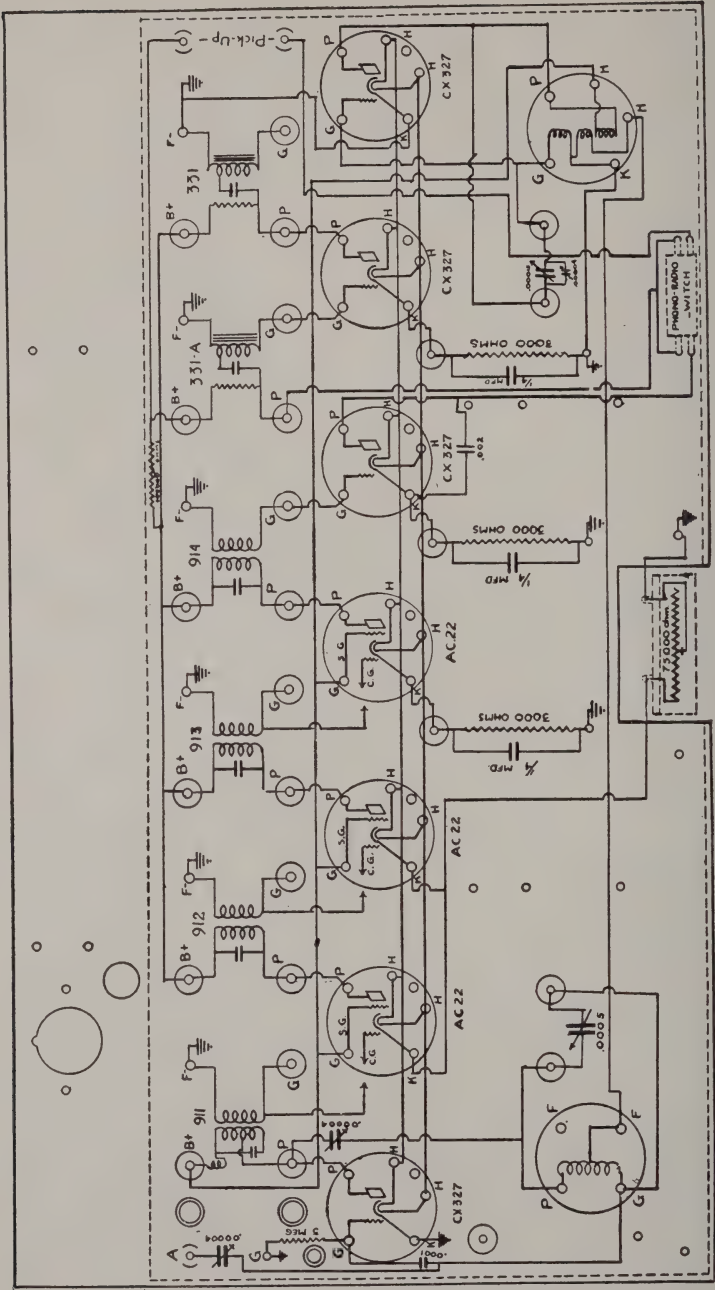


Fig. 38

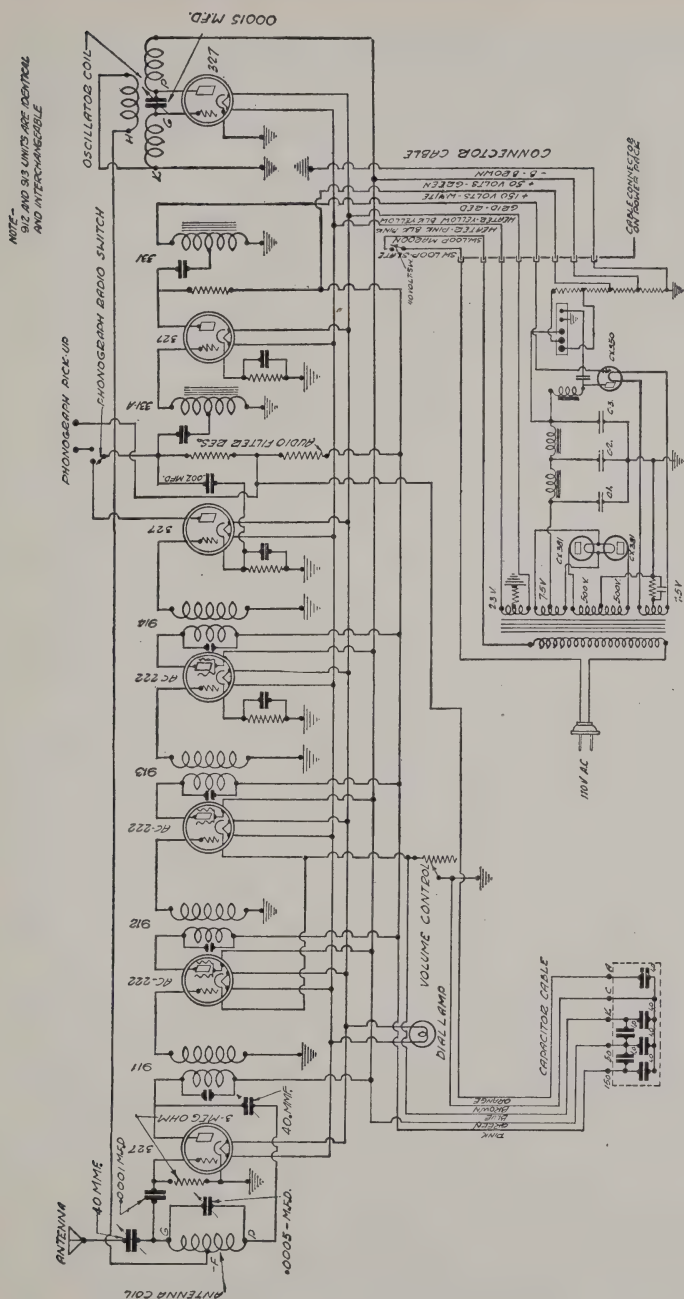


Fig. 39

chassis, so that a single unit contained all parts of the receiver. However, being of the custom-built variety, it was found that a few of the set builders occasionally experienced difficulty from hum. To guard against any such trouble, the engineers divided the units, furnishing the set and power unit separately, thereby eliminating any tendency toward magnetic coupling between the power units and the radio frequency stages. There seemed to be no logical reason for the coupling since all units including the tubes were individually shielded, but very likely a variation in tubes and resistors caused the signal to be modulated with an alternating current of 60 cycles.

In order that enough power be furnished to supply the 250 type tube, it is necessary to use two of the 281 type rectifiers.

The filter block which appears on the back of the chassis is not that used in the power unit but comprises all the by-pass condensers necessary for the receiver circuit, exclusive of the by-pass condensers across the grid bias resistors.

The grid bias is provided individually, a resistor being placed between the cathode and ground at each tube with the exception of the first and second intermediate stages. Here we find a connection that provides another method of volume control. The cathode of the first and second intermediate stages are connected together and their common connection is carried to one terminal of a 75,000-ohm rheostat. The arm of the rheostat is connected to the ground so that the variation of the value of the resistance regulates the value of the grid bias supplied to the two tubes. As the grid bias is varied, the plate current is increased or decreased accordingly and the volume is very effectively controlled.

The grid bias for the 250 type power tube is provided in the power unit. It is connected between the center tap of the 5-volt secondary winding and the ground or negative side of the line, placing the grid and filament at different potentials.

The power unit is designed to furnish the field current for an electrodynamic speaker. It is not essential that the speaker be of the dynamic type, however, since the terminals for the speaker field can be shunted either directly or preferably with a resistance of about 2500 ohms, having a carrying capacity high enough to dissipate the current, which is usually about .040 of an ampere.

The output of the 250 tube does not go directly to the speaker windings but instead is directed through an output filter unit which is included in the power pack. The high voltage is impressed upon the plate of the power tube through an audio choke coil. A condenser connected between the plate and the speaker supplies a current of alternating characteristics due to the charging and discharging of the plates of the filter condenser.

The superheterodyne circuit is provided with regeneration in the first detector stage, which tends to add to the sensitivity of the circuit. Care should be taken that the set is not placed in oscillation during operation, in which case difficulty would be encountered by reason of the station signals coming in at more than one setting of the dials because of the auxiliary signal set up in the set.

The superheterodyne circuit is one about which very little is written. Yet, it is no more difficult to understand than one of the standard radio frequency type. The intermediate stages are pre-tuned radio frequency stages, the tuning having been done in the process of manufacture.

The signal enters on the antenna or the loop, according to the type of input circuit used. If the loop is used, it acts as the pick-up, and is tuned by a variable condenser to select the frequency desired. If an antenna is used with the set, it is necessary that an antenna coupler be used, and the variable condenser that is used to tune the loop in a loop-operated set now tunes the secondary winding of the antenna coupler.

Another unit, known as the oscillator, enters into the circuit at this point. The oscillator is a stage entirely apart from the remainder of the circuit. Its function is to set up a wave at variance with the incoming signal. The energy from the oscillator is transferred to the circuit carrying the incoming signal through what is known as the pick-up coil which is the separate coil located at the top of the oscillator coil in Fig. 39.

So we find in the first detector tube a mixture of the two frequencies, the one coming in on the antenna or loop and another frequency generated in the receiver itself. Radio frequency transformers cannot be made so that they will tune equally well over a widespread band of frequencies, so in the superheterodyne circuit they are designed to pass one definite frequency to the exclusion of all others

and are so constructed that a narrow band will pass through. Superheterodyne circuits formerly employed intermediate amplifiers that would pass a frequency of approximately 50 kilocycles. Using such a system, the oscillator necessarily generated a frequency 50 kilocycles above and below the frequency that was coming in over the antenna system. The two frequencies meeting at the first detector tube created the 50-kilocycle frequency that was passed through the amplifiers.

Using a 50-kilocycle band-pass filter, as the intermediates are otherwise known, station signals could be received on two settings of the oscillator dial, since 50 kilocycles above or below any of the frequencies except those at the extreme ends of the range would still be within the reach of the tuning condensers. In order to remove one of the settings, the intermediate amplifiers were redesigned and tuned to a frequency which would keep the signals at only one spot on the dial. The Tyrman intermediates are tuned to a frequency approximating 475 kilocycles.

Take as an example of the old system, an incoming signal at 600 kilocycles. The oscillator must be tuned 50 kilocycles off that frequency, so that it might operate at either 650 or 550 kilocycles, both of which frequencies are within the broadcast band. Using the same basic frequency for the new system, it is found that 600 kilocycles modulated by a 475-kilocycle generated signal gives a resultant of 1075 kilocycles on one side and 125 kilocycles on the other. The 1075-kilocycle setting is within the broadcast band, while the 125-kilocycle frequency is well outside the range of the condenser and is not received on the set.

Since a single frequency is passed through the intermediate stages, it is evident that the shield grid tubes will function much better than they would if a wide variety of frequencies were impressed upon the grid. So we find that the shield grid tube is highly effective in a superheterodyne circuit, while its adaptation to tuned radio frequency circuits presents many problems.

Conversion of a D.C. Set to One Using A.C. Tubes. The conversion of a direct-current set into one using the alternating-current tubes is not a difficult matter; but when such a change is made, it should be done permanently without attempting a makeshift such as the use of a harness.

The principal change comes in the filament circuit and included in that change is a part of the grid circuit in that the grid returns must be changed. In this connection, the plate return is also affected, but the change in the plate return is simultaneous with the change in the grid return.

Fig. 40 shows the schematic diagram for a neutrodyne circuit employing the direct-current tubes. The standard form of neutralization is shown, and the changes in the circuit will be identical regardless of whether the form of circuit shown here is used or whether it be of the tuned radio frequency type or some other form of neutrodyne or superheterodyne circuit.

Notice in Fig. 40 that the grid return in the radio frequency stages is connected to the negative filament circuit and that the grid return for the first audio stage is connected to a 4.5-volt biasing battery. The value of the grid bias on the last audio tube depends upon the type of tube used—the 112 type uses a grid bias of 9 volts while the 171 type tube requires as high as 40 volts, depending upon the value of the plate supply.

The grid return for the detector circuit is placed to the positive filament, thereby biasing the grid of the detector stage positively, which is standard practice in the construction of direct-current sets.

Fig. 41 shows the schematic diagram for the same circuit shown in Fig. 40 adapted to the use of tubes of the UX-226 type in the amplifier stages, the UY-227 type tube in the detector stage, and a power tube of the 171 type in the final audio stage.

First remove all filament connections on the direct-current set. Cut off the connections between the filament circuit and the radio frequency transformers. Remove the grid leak if it be located in the position shown in Fig. 40, and place it across the grid condenser. Do not touch it if it is connected across the grid condenser, as shown in Fig. 41. It was placed in the circuit shown in Fig. 40 so that the receiver could be constructed with a gang condenser in which the rotors of the three or four capacity units were on a common shaft.

Remove the by-pass condensers connected between the different values of plate supply and the negative filament circuit.

Using a piece of standard hook-up wire make a connection to each of the grid return connections of all transformers in the radio frequency, detector, and audio stages, continuing the connection to the ground post of the set.

Procure a 10,000-ohm potentiometer and connect it across the primary of the first radio frequency stage with the arm of the unit connected to the antenna post, shunting it with a .001 microfarad fixed condenser to reduce the impedance of the antenna circuit.

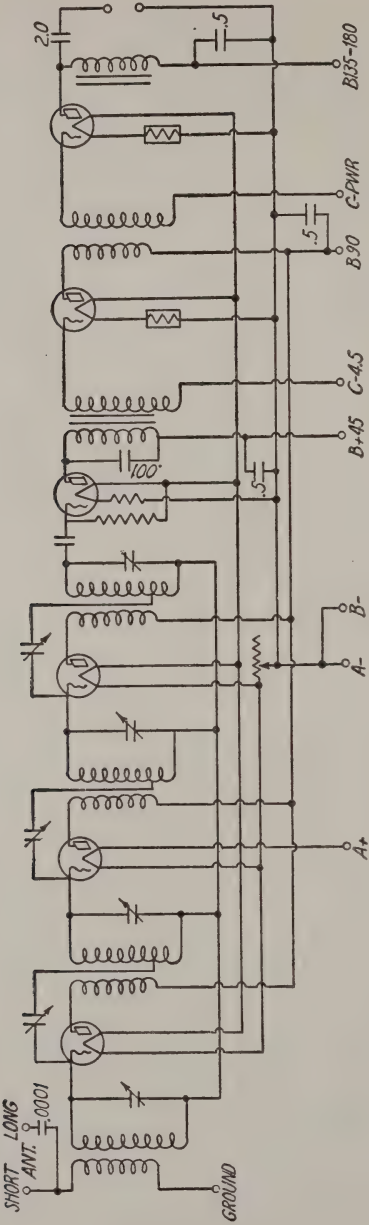
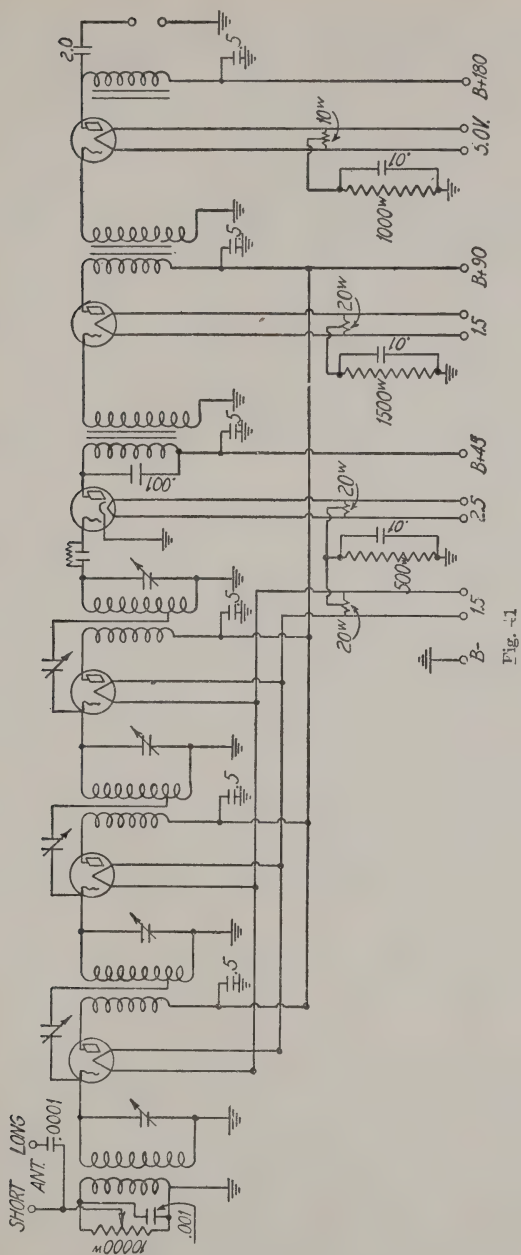


Fig. 40



Remove the detector socket and replace it with a five-prong socket to accommodate the heater type tube, the UY-227.

Use heavy wire for making the connections to the filaments of the tubes. Twisted pair No. 14 stranded is recommended since it will safely carry the current drawn by the tubes.

Provide a terminal strip on which are located two pairs of terminals for the 1.5-volt supply, one pair of terminals for the 2.5-volt supply, one pair of terminals for the 5-volt supply, in addition to the terminals for the negative B, the 45-volt supply for the detector, the 90-volt plate supply for the amplifier stages, and the 135- to 180-volt supply for the last audio stage.

From one pair of the 1.5-volt terminals make a connection to the filament terminals of the radio frequency tubes. While not essential, it is recommended that separate connections be made from the terminal strip to each of the sockets individually to reduce the voltage drop caused by the tubes.

Across this pair of 1.5-volt terminals shunt a 20-ohm potentiometer. The value of the potentiometer need not be 20 ohms, and in fact it may go down as low as 6 ohms, but the 20-ohm unit is recommended. The center arm should be left free for the time being.

From the pair of terminals provided for the 2.5-volt supply connect to the filament terminals of the 5-prong socket, using No. 14 twisted pair stranded wire. Across the terminals shunt another 20-ohm potentiometer.

Connect the arm of the potentiometer connected across the 2.5-volt terminals with the center arm of the potentiometer connected across the 1.5-volt terminals, and thence to one end of a 500-ohm fixed resistor as well as to one terminal of a .01-microfarad fixed condenser. Connect the other terminal of the 500-ohm resistor to the remaining terminal of the condenser and thence to the ground or to the lead which was formerly made to connect the grid return terminals of the transformers.

The value of the resistor just connected into the circuit is determined by using Ohm's law, $E = IR$. There being three tubes, each drawing between .003 and .0035 of an ampere, making a total of about .010 of an ampere, and a biasing voltage of 5 volts to be supplied to the tubes, it is found that the value of the resistor should be approximately 500 ohms, 5 being the value of E , and .010 being the value of I .

Before proceeding to the audio stages make a connection from the cathode terminal K of the detector socket to the ground or the grid return of the transformers.

From the other pair of terminals on the terminal strip for the 1.5-volt filament supply make a connection to the filament terminals of the first audio tube socket. Across the terminals connect another 20-ohm potentiometer connecting the center arm of the potentiometer to one end of a 1500-ohm resistor and to one terminal of a .01-microfarad fixed condenser. Connect the other end of the resistor and the condenser to the ground, thus providing a 5-volt bias for the grid of the first audio tube as calculated from Ohm's law.

From the filament terminals of the last audio tube, make a connection to the pair of terminals on the terminal strip to provide the 5-volt filament supply. Across the terminals shunt a 10-ohm potentiometer and from the center arm

make a connection to one end of a 1000-ohm resistor and one terminal of a .01-microfarad fixed condenser. Connect the other ends of the resistor and the condenser to the ground to provide the grid bias for the last audio tube.

The connections at the speaker terminals may vary, but if the output circuit uses the filter shown in the diagram, one of the terminals, the one which was formerly connected to the negative filament circuit, should be connected to the ground.

Between the B battery connection to each of the transformers connect one end of a .5-microfarad by-pass condenser, connecting the other end of the condenser to the ground. These serve as paths for stray radio frequency currents that might be set up in the power supply unit.

The wiring of the set is now completed. Procure a transformer that has two 1.5-volt windings, one 2.5-volt winding, and one 5-volt winding. If a transformer with the two 1.5-volt windings is not available, a single winding will suffice, but the two-winding unit is recommended.

If it is desired to construct a filament transformer, the specifications given in the section on power units will serve as a guide.

There is not so much changing of the circuit to adapt the radio set to the use of UY-227 tubes in the amplifier stages, but it is necessary to change all sockets with the exception of the one for the last audio tube. Fig. 42 shows schematically the wiring of the circuit using the heater type of tubes.

Follow the instructions given for removing the filament and grid return connections in the set and make the connection between the grid return terminals of each of the transformers and the ground.

The terminal strip for a set employing the heater type tubes throughout needs terminals for two 2.5-volt supplies and a 5-volt supply, in addition to the standard terminals for the plate supply unit.

Use wire not smaller than No. 12 stranded if the tube sockets are connected in parallel; while if they are connected individually from the terminal strip, No. 14 stranded wire will suffice. Use twisted wire for making the filament connections to eliminate any effect from the alternating current.

From the cathode terminal *K* of each socket, except the detector, make a connection to one terminal of a 1500-ohm fixed resistor and one terminal of a .01-microfarad fixed condenser, connecting the remaining terminal of each resistor and condenser to the ground.

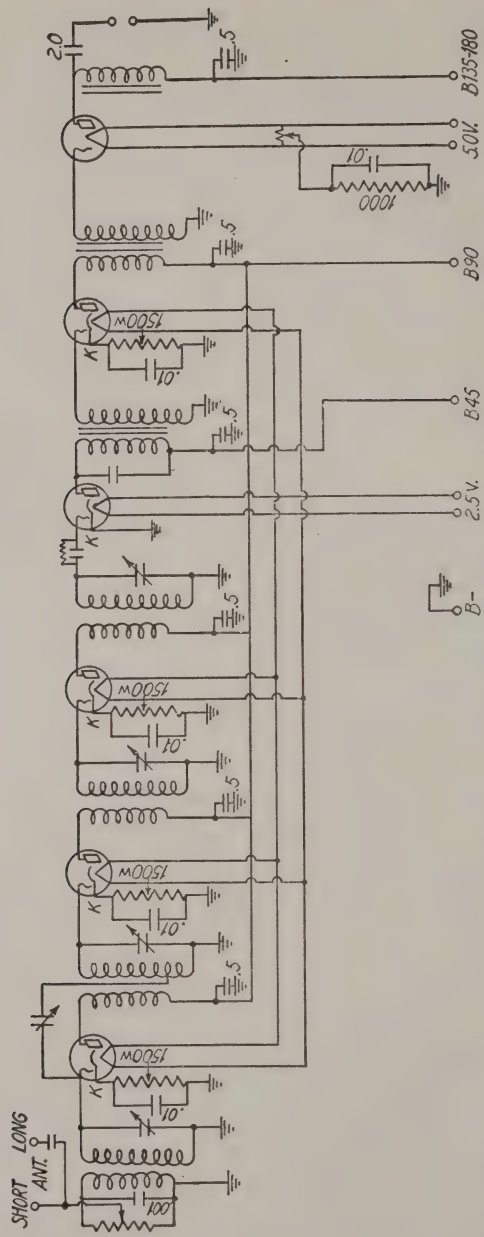


Fig. 42

In this way a grid bias of approximately 5 volts is provided for each stage individually. The cathode of the detector socket connects directly to the ground without going through a resistor.

Follow the instructions for the receiver using the 226 type tubes for the connections for the power tube. Make the connections to the filament of the detector tube from a separate winding on the transformer if possible. If it is not convenient to procure a transformer that contains the two 2.5-volt windings, a single winding will serve the purpose, but the two are much to be preferred.

Connect the by-pass condensers into the circuit as explained in the instructions for the circuit shown in Fig. 41.

While it is not necessary to connect the potentiometer across the 2.5-volt terminals, a 20-ohm unit may be used if desired. The center arm of the potentiometer should be connected to ground and will serve as a means of eliminating any tendency to hum, though there is not a great deal of danger of hum developing when using tubes of the heater type.

TROUBLES

Trouble with alternating-current sets may be classified under three headings: failure to function in any respect, noisy operation, and poor reproduction. Each of these is taken up in order, with methods of procedure, to determine the cause as well as the means of correcting the difficulty.

Failure to Function. The first thing to look for when the set fails to function is a burned-out tube. With tubes of present-day quality there is not such a likelihood of tube failure as there was when alternating-current tubes first came into use, but a radio tube will burn out just the same as an ordinary incandescent lamp. If the tubes light, it is reasonably certain that at least some sound will come through the reproducer, although the reproduction might be anything but satisfactory.

Presuming that the tubes are working satisfactorily, the first step is to test the reproducer. In order to do this, use a set of headphones or another reproducer, the headphones being preferred. Often sounds are heard through headphones that are passed over when a loud-speaker unit is connected to the set. In this case we shall assume that the reproducer is in good operating condition.

The burning out of one of the grid resistors is one of the most common forms of receiver failure. Oftentimes this can be determined at once, but again it will require a great deal of searching. One of the best methods of testing is to use a voltmeter with a scale reading as high as 150 volts. Mount the voltmeter in a frame that will allow it to set up where you may observe it as you check the connections. Take the chassis out of the cabinet and locate the resistors on the underside of the panel. With the set turned on take the two leads from the voltmeter, go over the resistors, holding one lead on one terminal and placing the other lead at the opposite end of the resistor. When the defective one is found, a sound will be emitted from the reproducer. It is well to adjust the dials to some local station while making this test so that there will be more than a click in the speaker when the proper connection is made. The resistor may then be replaced with a new one or, in case of an emergency, a turn may be removed from the old one and a temporary connection made. In one case where this trouble arose it was found that the resistance wire had been improperly connected at one terminal and it was only necessary to clamp the connection once more.

The cause for a failure of this type is often due to the sudden turning on and off of the power supply. Ordinary operation of the set switch will not be likely to cause it, but if the plug is loose in the receptacle and is touched so that the contact is intermittently made and broken two or three times, the discharge of the condensers might be taking place at just the time when the alternating current is on the upward part of the cycle, and the added current will overtax the carrying capacity of the unit.

If the resistors are found to be in good condition, the next step is to trace through with the voltmeter every other connection in the set to find an open circuit in either the wiring or the transformer units. A closed circuit can be easily determined in most cases due to the fact that heat will be generated and the workings of the radio set will emit an odor that is readily detected.

After making these simple tests, the best plan is to return the unit to the service station if the trouble has not been found, for breaking into the sealed portion of the set would entail a great amount of work and it is very likely that the manufacturer's service man

could determine the cause of the trouble without unnecessary delay.

Noisy Operation. There are many different types of noise that enter into radio reproduction, and it is up to the service man to differentiate between them. Several of these noises are caused by external sources such as power lines, signs, electric railways, X-ray machines and other high frequency generators, telephone vibrators in country districts, and even the light lines within the home. On removing the antenna from the set, if the noise stops, it is reasonably certain that the noise is not in the set; but if it continues, then it is necessary to investigate the receiver chassis to find the cause and eliminate it. In the preliminary investigation the receiver should be moved from its location in the room in order to separate it from any inductive relation with electric wiring and in addition to that the plug in the receptacle should be reversed.

Noisy operation of a radio receiver, if not caused by outside sources over which the service man nor the radio set owner have no control other than to bring pressure to bear to cause the elimination at the source, is usually caused by loose connection, defective tube, defective condenser plates, hum, or static.

Loose Connection. A slight shake of the chassis before beginning any investigation will serve to show whether or not a loose connection is causing the disturbance. If there is a decided make and break in the circuit, then each wire should be shaken until the offending one is found. It is not very often that a loose connection can be spotted on sight, for the connection may seem to be in perfect condition but be held away from the other part of the terminal by a grain of rosin from rosin core solder or some other foreign substance. A soldered connection might also have become broken from crystallization or other causes and intermittently make contact.

Defective Tube. Any tube of either the amplifier, detector, or rectifier type can cause noise in the set. The only way to determine such a defect is to try known good tubes in each socket in place of the ones used there. Sometimes a tube is microphonic and sets up vibrations in accordance with the sound waves from the reproducer. These sounds cause the elements of the tube to vibrate, emitting a howl from the speaker. The louder the howl the more

the elements of the tube vibrate until the howl becomes unbearable. A rubber cushion surrounding that tube will sometimes eliminate the trouble, but the best policy is to eject the tube and replace it with a good one. The rectifier tube may cause noise if it becomes ionized or has been paralyzed. In the case of heater type tubes, if the filament is encased within a hollow tube, it may fall too far toward one side of the cathode and cause a hum. A slight jar against the hand sometimes serves to right the wire and stop the disturbance.

Defective Condenser Plates. The determination of trouble from defective condenser plates can usually be determined by turning the tuning dial. Signals will ordinarily come in over a certain portion of the dial and then the remainder of the range will be dead. It is likely that the scraping of the plates can be heard as well. The only method of correction is to find the offending tuner and straighten the plates or adjust the bearings so that the plates will be centered with reference to the stator. The readjustment of the rotor plates of a condenser will necessitate the realignment of the trimmer condenser, which may usually be done by the ear method by determining the proper setting for the greatest volume. The alignment of the trimmers is not like that of the neutralizers where the tube filament must be left out of the circuit. It is not always true that the condenser plates must scrape in order that difficulty from this source is encountered. A metallic chip may fall between the plates and intermittently or continually cause a short circuit between the rotor and stator elements of the unit. It can be removed by using a pipe cleaner or piece of paper and once removed should be carefully removed from the chassis to prevent further trouble.

Hum. First, make sure that the hum is not caused by induction from power lines, and then reverse the plug in the receptacle. With these precautions taken and the hum still existing, it may be caused by a loose lamination in the power transformer, a short circuit between the filament wiring and the chassis, an open or short-circuited center tap resistor, or a defective tube.

A loose lamination in a power transformer can be heard if the ear is placed in the proximity of that unit. The only remedy is replacing the unit. It is not recommended that the sealing compound surrounding the core of the transformer be tampered with by other than those who are equipped to remove and replace it. Too

much heat applied to the unit may result in changing the characteristics of the windings that would prove disastrous later on. If the transformer is of the open type with no sealing compound, the difficulty can be overcome by tightening the screws that hold the laminations together.

Having determined that the hum is not caused by the loose lamination, look over the chassis carefully to see if there is a short circuit between the filament circuit and the chassis. This short circuit may occur at any point, including the dial light. The remedy is to separate the contacts and provide an insulator to prevent a recurrence of the trouble.

Center tapped resistors are for the purpose of balancing out the electromagnetic field in the tube. It is evident that if one side of the resistor is open, the alternating current on one side of the zero line is affected. Similarly, if one side of the resistor is short circuited, that portion of the circuit is out of commission and the resistor must be replaced with a good unit. The easiest method to find this is to use an alternating-current voltmeter with a low scale. The reading between the center tap of the resistor and either side of the filament line should be only half of that across the filament terminals. If the reading obtained is just slightly less than that across the outside terminals the circuit is open. Look also into the condensers that by-pass the center tap resistors, since a short circuit there will be the same as a short circuit across one side of the resistor.

Static. When radio first came into being, static was an atmospheric disturbance due to electricity in the air. Since that time, many have attempted to make static eliminators, none of which have been entirely successful. It is now a known fact that much of the so-called static is caused by electrical apparatus used in the home and on the outside. The only way to combat static at the present time is to catch it at the source.

Poor Reproduction. A receiver may be operating, but not at full efficiency, and the poor reproduction may be caused principally by defective tubes, low voltage, improper grid bias, defective speaker, interference from broadcasting station, harmonics, heterodyning, incorrect length of antenna, grounded antenna, poor ground, condensers out of alignment, circuit out of balance, defective volume

control, poor connections, fluctuations of line voltage, inefficient transmitting, or static. Any one of these conditions will seriously affect the operation of a radio receiver. Under some conditions the difficulty can be overcome by a service man, while in other cases the set owner is at the mercy of the elements.

Defective Tubes. A defective tube at any location in the receiver or power unit can cause difficulty in the reproduction. Each type of tube has its characteristic noise, however, so that it may usually be distinguished from the others. The rectifier tube will oftentimes light, if it is of the thermionic filament type, but at the same time it may not be functioning properly. Reception may be satisfactory for a short time. Then there will be a sudden drop and sometimes a hissing sound, after which the receiver may stop functioning. If the set is turned off for a time and then turned on, it will probably operate again for a short time. Again the defective rectifier tube will cause a crackling sound similar to that caused by run down B batteries.

The amplifier tubes of the 226 type can be checked for burned-out filament. Reproduction will become very weak from a poor amplifier tube, but it is not likely that any particular noise will result. Since the tubes are easily tested, it is recommended that they be checked on first investigating a set to determine whether or not the trouble comes from this source before proceeding to other causes that may be harder to locate.

The check-up of the detector and power tubes is exactly the same as that for the amplifier tubes. A heater type detector tube may appear to be functioning but may have become weak in electronic emission, a condition that can be found by placing it upon a test panel. The filament element of the detector tube makes a loop through the isolantite cylinder in the center of the tube. If the insulating characteristic of this material breaks down, the result will be a partial short circuit that will cause the tube to be inoperative by reason of the alternating current following through the insulation rather than following the filament circuit. If the power tube is defective, it usually causes a rattle in the reproducer.

Low Voltage. If the value of the electrical energy that is supplied to the filament or plate of the tubes is too low, the reproduction will become weak. A voltmeter is the only instrument for

determining this condition. If the filament voltage is low, it may be caused by a short circuit at some point or by a defective winding on the power transformer. Low voltage on the plate supply may be caused by a defective winding on the power transformer or a short circuit at some point in the voltage divider or filter circuit. The tests may be made in the power unit with the aid of a voltmeter of the direct-current type in checking the plate supply, but an alternating-current meter should be used in checking the filament supply for the alternating-current tubes.

Improper Grid Bias. Improper grid bias may be caused by the failure of a grid biasing resistor or by a short circuit in the resistor or its condenser. Check the grid biasing resistors with a voltmeter and if the trouble is not located, check the chassis for a short circuit at the resistors or the by-pass condensers shunted across the biasing resistors. The values of the grid biases should usually be 5 volts for the amplifier tubes while about 40 volts will be provided for the 171-A type of power tubes or about 9 volts for a power tube of the 112-A type.

Defective Speaker. Perhaps the speaker is the first thing that should be checked in going over a set. Some units have an adjustment for the armature or diaphragm, and a simple adjustment of that part of the reproducer will put everything into shape again. One method of determining whether or not the receiver is delivering a steady output to the reproducer is to connect the voltmeter into the speaker terminals of the set and see if the needle is fluctuated readily. Understand that the needle will not remain constant, but will fluctuate with the pulsations that come through the receiver output. There is no definite reading that can be obtained, but the service man can easily determine whether or not the output is sufficient to actuate the speaker properly.

Interference from a Broadcasting Station. Unless a broadcasting station is equipped with a device such as a crystal for maintaining constant frequency, the wave is very likely to swing. In other words, the peak of the wave will be tuned in at one setting of the dial at one time, and then the signal will die down in intensity only to be found peaked at some other point on the dial. Such a condition is distracting and can only be remedied by bringing pressure to bear upon the station itself. A local broadcasting station may

"blanket" the band due to the broadness of the transmission (caused principally by defective equipment or incorrect antenna) or feedback through the power lines. Again the remedy lies with the station and, so far as the set is concerned, although there is no assurance that success will reward the efforts, a wave trap might be tried.

Harmonics. Here again the trouble is more likely to occur where there is a nearby broadcasting station. It is not likely that the trouble can be traced to the receiver unless the circuit is that of a superheterodyne type. If the superheterodyne circuit is one employing regeneration, it is possible to adjust the regeneration condenser so that the set is in oscillation and brings in stations on more than one reading of the dial. This is true of the "one-spot" supers as well as those employing the longer wave intermediate filters. The remedy, then, in the case of the superheterodyne is to keep it out of oscillation. No harmonics should be tuned in on a radio frequency or neutrodyne type of receiver unless forced through from the transmitter itself, and relief must be obtained at that point. Harmonics can be distinguished from the "blanket" by the fact that they come in at a point just double the frequency upon which they operate and again at just half the rated frequency. If, then, the station is operating on a frequency near the top of the band, it may be troublesome down in the lower end of the band, and vice versa. Those stations having frequencies in the center of the band will not be found to set up harmonics within the range of the broadcast receiver.

Heterodyning. Heterodyning is the high-pitched whistle that is heard when tuning in a station on a frequency near that of another station. The more sensitive the set, the more heterodyning there will be unless the set is selective enough to overcome the interference. The interference is caused by the waves from the two stations overlapping and the whistle is a beat between the edges of the two waves. Heterodyning is difficult and sometimes impossible to overcome. A receiving set that is fairly selective will eliminate a great deal of the interference if the tubes are operating efficiently. While there is no definite assurance that all heterodyning will be eliminated—and in fact it can almost be said definitely that it will not be stopped completely—it will be found that there is less interference from this

source when the weather is such that the signals are strong enough that the volume control does not have to be turned on full.

Heterodyning is more likely to occur when one of two stations is operating on a frequency slightly off that to which it has been assigned. In this case, the station operating in the channel toward which the offending station is leaning will be affected as well as the station which is not operating upon its assigned frequency. The top of the modulated wave mixes with the wave of another station and the high-pitched whistle is carried into the signal of both stations.

Incorrect Length of Antenna. The correct length of the antenna can be determined by finding that length which will permit the antenna trimmer to take a natural position about the center of the swing. An antenna too long will cause the trimmer to require a setting beyond that which it is capable of reaching. An antenna too short will mean that the trimmer must reach a value below that which it is possible to obtain. These conditions might be reversed according to the type of unit and method of connecting the antenna trimmer used in the circuit.

Grounded or Partially Grounded Antenna. A grounded antenna will be indicated by weak signals even from nearby stations. A partially grounded antenna will cause fluctuations in the reception and with each complete grounding the reception will drop off with a decided click.

Poor Ground. A poor ground will cause a variety of noises. Among them will be found weak signals and a sort of static. The best method of making the ground connection is to use a standard ground clamp. In this way the connection is made directly into clean metal; whereas, if the wire is wrapped around the outside of the pipe, the section which may be cleaned when the connection is first made will corrode and the resistance set up by the corrosion will seriously affect the reception of signals. If the ground connection is made on one part of the plumbing system, it would be well to use another pipe, because at some point in the first pipe used there might be a connection that would be effectively insulated from the remaining part of the system, through no fault of the plumbers but merely an accidental instance.

Condensers Out of Alignment. Naturally when two or more condensers are operated on a single controlling shaft they must be

aligned to a degree bordering on perfect. There can be but a very little deviation, otherwise the reproduction will be very seriously affected. Such a condition is made manifest by the fact that some stations come in weak, in others the tone will be muffled due to the cutting of side bands while the signal is passing through one or more of the stages of radio-frequency amplification. Condensers out of alignment will also cause the receiver to tune broadly in many instances. The defect can be remedied by noting the condenser to see if any of the plates appear to be bent. If so, they should be straightened to correct the deficiency. A trimmer condenser is mounted on the frame of most tandem condensers for the purpose of correcting for any discrepancies when they occur over the entire swing of the condenser. If it is found that the trouble occurs from one end of the band to the other, then it can be overcome by adjusting the trimmer condensers. Aligning of the condensers is also called phasing. The service man will be called upon to depend largely upon his own ingenuity in correcting for poorly aligned condensers.

Circuit Out of Balance. It will be necessary for one checking over the set to have a diagram of the set upon which he is working in order that he may know where the neutralizing condensers are located. A dummy tube for use in neutralization can be made by cutting off one of the filament prongs so that no current can flow through the filament element. A burned-out tube will not serve the purpose. If the five-prong type of tube is used as the amplifier in the stage to be neutralized, one of the filament prongs should be cut off rather than the prong connecting to the cathode, as would be considered on first thought. No matter what the set, the principle of neutralization is the same. Tune in a station, remove the first radio-frequency tube, and put the dummy tube with the filament prong cut off in its place. Turn the neutralizing condenser until the signal disappears entirely or reaches a minimum, for sometimes it will be found that a signal seeps through regardless of what setting is given the neutralizing condenser. Incidentally, a set of headphones should be used in place of a loud speaker in making these adjustments. It will be found that on turning the condenser further than the point where the signal disappears, it will begin to reappear. Note the point at which it leaves off and the point

where it takes up again and set the condenser midway between these two points. Replace the good tube, retune the set, and proceed to the second radio-frequency stage, repeating the operation until all stages have been neutralized.

Defective Volume Control. A defective volume control causes a cracking sound when the control unit is turned. It will also cause a sudden break in the reception. The remedy for it is to disassemble it if possible and spring the sweeper toward the resistance element so that definite contact will be made around the entire sweep. If the control unit is of a type that cannot be readily taken apart for such an adjustment, the only alternative is to replace it with a new unit.

Poor Connections. Poor connections cause crackling noises in the reproducer. They can be accentuated by jarring the chassis and if they are found to exist, then it is necessary to carefully go over all the wiring of the set to find where the poor connections are located. Here, too, a poorly soldered connection can cause poor reproduction due to the resistance that is set up in the improperly soldered joint. It should be remembered that in order to make a good soldered connection, the solder must flow into position. Cold solder causes as much trouble as any other one thing in a radio set.

Fluctuations of Line Voltage. In this cause of trouble the set owner is at the mercy of the power company. The power company cannot be held liable, either, for it has no way of telling offhand just what the line voltage is at any single part of the system. The drops in the voltage are due to the loads that are placed on the transformers. In the crowded areas it is not out of the ordinary to find a transformer for each block and sometimes they are placed more than one in a block. While the power supplied to each of the transformers is equal, the secondary output of one of the transformers might be five volts lower than from another, due to the load that is placed upon it. With the taking off of a heavy load, the voltage will surge upward. In some of the present-day receivers a resistance ballast is installed in the primary circuit to guard against such fluctuations. With such an arrangement the intention is not to keep the line voltage at the ordinary rating of 110 volts, but rather to decrease it so that the actual voltage that is impressed upon the primary of the transformer is around ninety volts. Fortunately, the action of the alternating-current tubes is much slower than was the

case with the direct-current tubes so that they are not affected by instantaneous rushes of current.

Static. Natural or man-made interference is known as static. For the natural static there is no relief, but all man-made static can be eliminated either entirely or nearly so, but it must be trapped at the source. Filter circuits must be especially designed to stop the arcing that causes the distinctive crackling that is so distracting to radio reception.

In addition to these principal difficulties that will be found to arise in alternating-current receivers, service men will be confronted with the complaint of the failure to receive distant stations. Since there are so many variable factors that enter into radio reception, there is no one who can say that any receiver, no matter what the size or strength of the set, will get any particular amount of distance. Reception of distant stations depends to a large extent upon sensitive tubes, and the service man will do well to carry with him a sample or two of good well-selected sensitive tubes, particularly of the detector type, for it is at that stage that the sensitivity of the set is really determined.

SHORT-WAVE RECEPTION

Reference to short waves in radio means that portion of the radio band below 200 meters—the lower extremity of the broadcast band. The band is divided into several sections, those divisions having been determined by the Department of Commerce acting in cooperation with similar departments in foreign countries. During the last few years several of the broadcasting stations have taken licenses to operate on the short waves simultaneously with their long-wave broadcasting in order that their programs might reach into remote districts, since the short waves have the property of covering much wider areas than the long waves.

Short waves are not as reliable as the long waves, however, particularly so far as local broadcasting is concerned because they are subject to what is referred to as skipping. Short-wave transmission might be entirely ineffective a very short distance from the transmitter, while hundreds or even thousands of miles away the signal can be picked up readily. Short waves are also used in rebroadcasting, but only in isolated instances.

The controlling of the short waves is identical with that of the long waves. The wave is received over an antenna, directed through the antenna coupler, impressed upon the grid of the tube, tuned through the secondary circuit of the radio frequency amplifier, and picked up at audio frequency from the plate of the detector tube.

A single tube is sufficient for most purposes in the reception of short-wave signals, but if it is desired to use a loud speaker in the reception, then the output of that tube must be directed through a two-stage audio amplifier of standard design. Headphones must be used when the single tube receiver is used. A stage of radio frequency may be added ahead of the detector to amplify the incoming signal before it is detected, if desired.

Due to the fact that inductance units cannot be made to operate efficiently over a wide range of frequencies, it is necessary to use

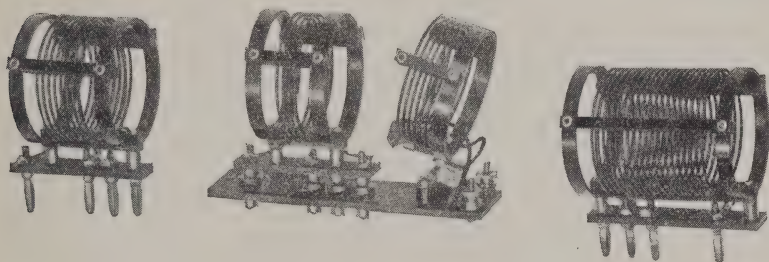


Fig. 43

a variable condenser of much lower capacity than is used in the reception of broadcast signals and then to use a number of coils. Coils of the plug-in type are used almost exclusively, each coil covering a small portion of the band between 15 and 200 meters.

The operation of a short-wave receiver is more reliable when batteries are used for the power supply, due to the fact that the high frequencies are susceptible to the action of the low frequency alternations from the light current. If alternating-current operation is to be used, the heater type of tubes should be used to the exclusion of tubes of the 226 variety.

The coils used for tuning a short-wave receiver are shown in Fig. 43. Note that there are three coils, each of which has four terminals that fit into the jacks provided on the mounting strip. One of the coils is shown plugged into position. Each of the three

plug-in coils contains two windings, the grid winding and the plate or tickler winding, to provide regeneration. The secondary coil is space wound, the spacing being not less than the diameter of the wire. By space winding the coils the distributed capacity of the coil is materially reduced, thereby eliminating a feature that would affect the tuning of the inductance.

The specifications given below may not conform to the illustration in Fig. 43 in all respects, but are given for the benefit of those who wish to experiment with short-wave coils in their home laboratories.

The primary coil has 16 turns of No. 24 D.S.C. wire and remains the same for all coils. It is an integral part of the coil mounting, hinged to allow a variation in the amount of energy delivered to the secondary coil by controlling the degree of coupling. Other specifications are given in Table I.

TABLE I

Tuning Range in Meters	Diameter of Coil Inches	Turns on Secondary	Size and Kind of Wire	Turns on Tickler	Size and Kind of Wire
8.2 to 32.0	2	3	#14 enamel	3	#28 D.S.C.
19.1 to 48.7	2	8	#14 enamel	3	#28 D.S.C.
36.2 to 89.5	2	19	#14 enamel	4	#28 D.S.C.
64.0 to 155.0	2	31	#24 D.S.C.	6	#28 D.S.C.
125.0 to 250.0	3	40*	#24 D.S.C.	15	#28 D.S.C.
250.0 to 550.0	3	98*	#24 D.S.C.	20	#28 D.S.C.

*Close-wound, spaced only with the thickness of the insulation.

From Table I it will be seen that a single receiver can be adapted to a tuning range from 8.2 meters to the top of the broadcast band. In fact other coils could be used to tune into the extremely long waves. The reason for the large number of turns on the coils in the broadcast band is that the condenser used for tuning through the entire range of frequencies has a capacity little more than half that usually employed in broadcast receivers.

The circuits used for the reception of short-wave signals are of the regenerative type. Old-type superheterodyne circuits using the 45- and 50- kilocycle intermediate transformers did not function so well in the short waves. Later models of superheterodyne receivers

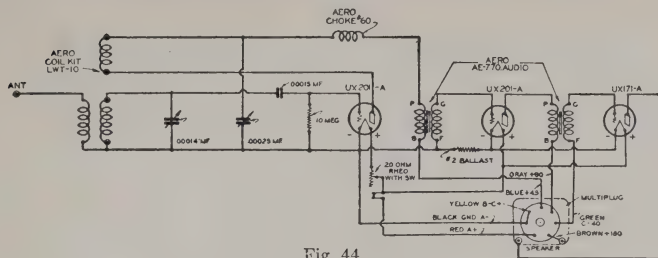


Fig. 44

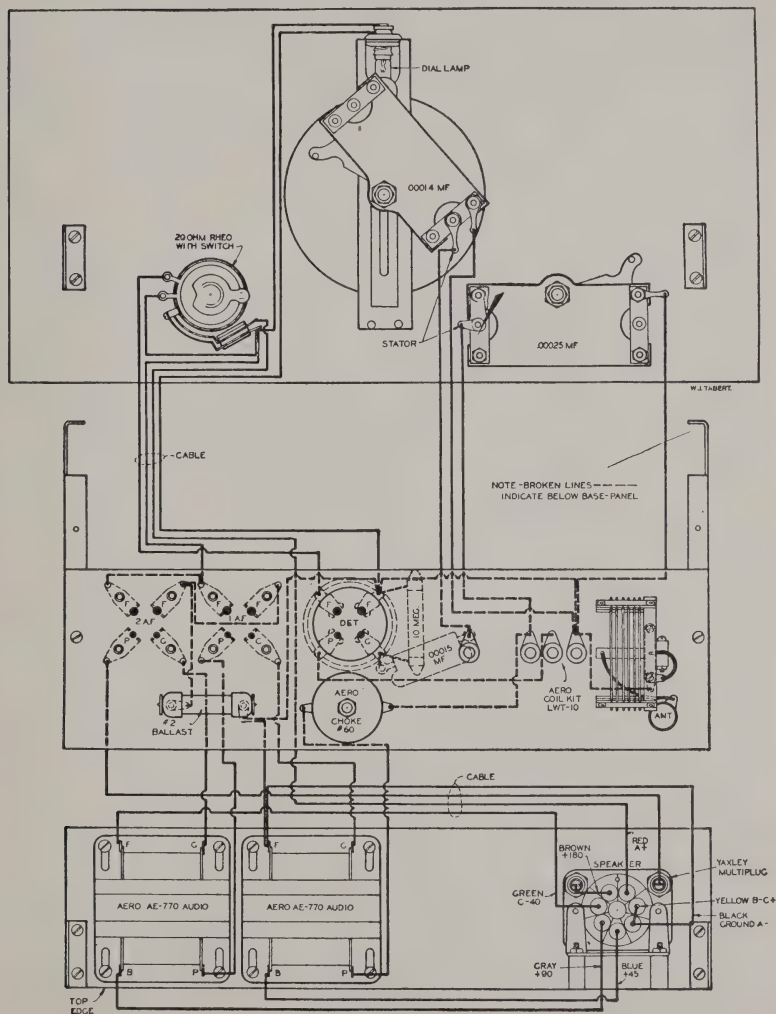


Fig. 45

that pass a much higher frequency are better suited and can be used with a fair degree of efficiency by providing a set of plug-in coils to reach the short waves.

SHORT-WAVE RECEIVERS

There are several forms of short-wave receivers. A three-tube direct-current receiver, a three-tube alternating-current receiver, a four-tube receiver using a radio frequency stage employing the shield grid tube, a two-stage converter to be used in connection with the audio stages of a standard receiver (the shield grid tube is used in this circuit also), a direct-current short-wave adapter employing a single detector stage, and an alternating-current short-wave adapter for use with alternating-current sets will be taken up in the order in which they have been enumerated.

Three-Tube Direct-Current Receiver. The three-tube direct-current receiver, shown in Fig. 44, includes a single tuning stage together with a two-stage audio amplifier. It is designed for use with a loud speaker, employs tubes of the 201-A type in the detector and the first audio stages, and a 171 type tube in the last audio stage.

The circuit in the tuning stage is that of a reactance regenerative circuit where the regeneration or feed-back is controlled by a variable condenser connected between the tickler coil and the ground or grid return. A .00014-microfarad variable condenser is used to tune the secondary coils of the kit while a .00025-microfarad variable condenser regulates the amount of energy that can pass into the grid circuit from the plate circuit.

The choke coil shown in the plate circuit is a necessity when

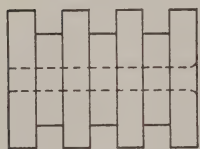


Fig. 46

working with short-wave receivers, since the radio frequencies that enter into the audio system have a serious effect upon the operation of the set. The choke coil shown is wound on a spool that has three slots, as shown in Fig. 46. The choke coil 60 contains 600 turns of No. 36 wire, 200 turns being placed in each of the slots.

The ballast shown between the negative filament terminal of the first audio tube and the *F* terminal of the first audio transformer is for the purpose of supplying a negative bias to the grid of the first audio tube.

The connections for the set are shown in Fig. 45. The full details of the wiring are shown in the illustration and, if carefully followed together with the diagram in Fig. 44, there should be no difficulty in constructing a direct-current short-wave receiver.

Three-Tube Alternating-Current Receiver. The circuit for the short-wave receiver employing a single tuning stage and a two-stage amplifier shown in Fig. 47 is identical with that shown in Fig. 44, except that heater type of tubes are used instead of the 201-A tubes. The filament and grid return connections are changed to meet the requirements of the tubes, but the circuit in other respects is the same. The wiring diagram is shown in Fig. 48.

Four-Tube Short-Wave Receiver Employing the Shield Grid Tube. In Fig. 49 there is shown the schematic diagram for the construction of a short-wave receiver using the shield grid tube in a stage of untuned radio frequency ahead of a regenerative detector. The wiring diagram is shown in Fig. 50.

This circuit differs from the standard type of receivers in many respects. The antenna couples directly to the grid of the shield grid tube and to one terminal of a radio frequency choke coil. The other end of the choke coil connects to the negative filament circuit or to the ground, which are common. The specifications for the choke coil shown in the antenna stage of Fig. 49 call for 225 turns of No. 36 wire wound on the form shown in Fig. 46. The windings are divided between the slots, 25 being placed in one, 75 in the next, and 125 in the third.

Ninety volts is supplied to the shield or outer grid of the tube and that voltage is by-passed to the filament circuit through a .003-microfarad condenser to drain off excess radio frequency currents.

The primary winding of the short wave-kit is not used in the detector stage of the receiver using the shield grid tube. This is due to the fact that the impedance of the plate current must be varied to meet the output impedance of the tube itself. The .00014-microfarad condenser that is used to tune the grid circuit of the detector stage aids in adapting the output circuit to the tube plate output.

The circuit in the detector stage should be very carefully studied. Notice that the tuning condenser is shunted across the secondary coil of the kit, and that the secondary coil is not connected to the filament circuit, but rather through a choke coil to the high voltage

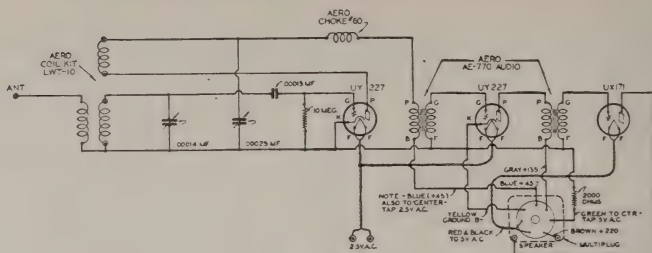


Fig. 47

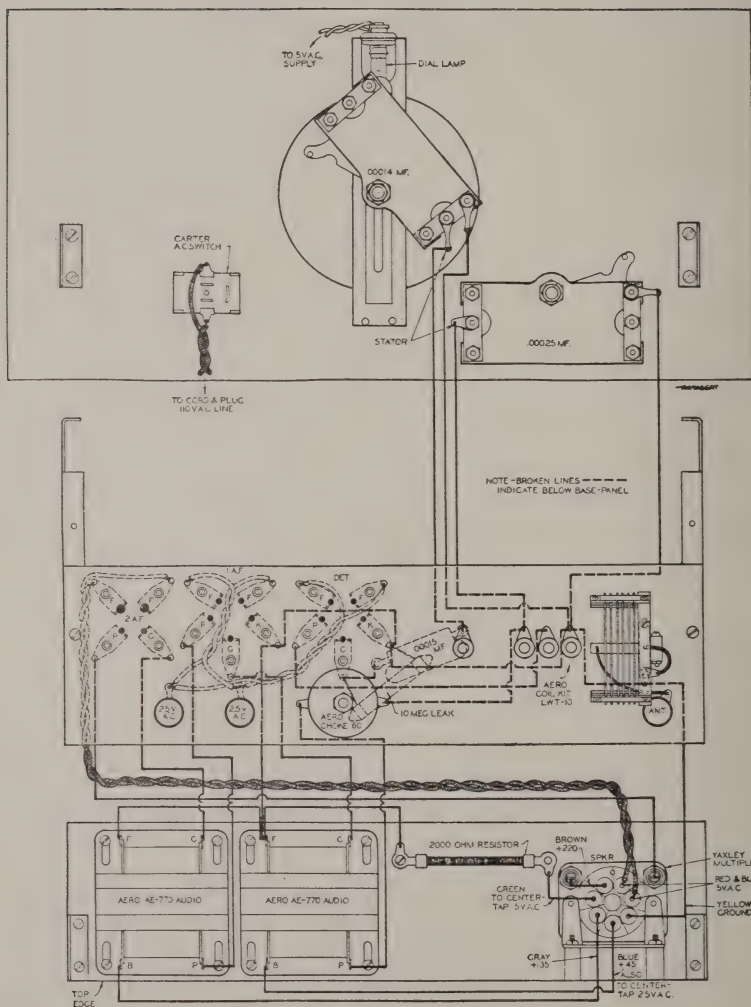


Fig. 48

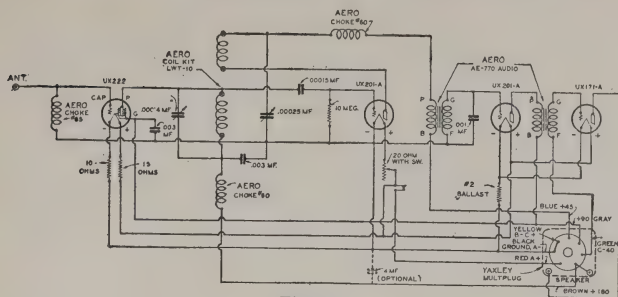


Fig. 49

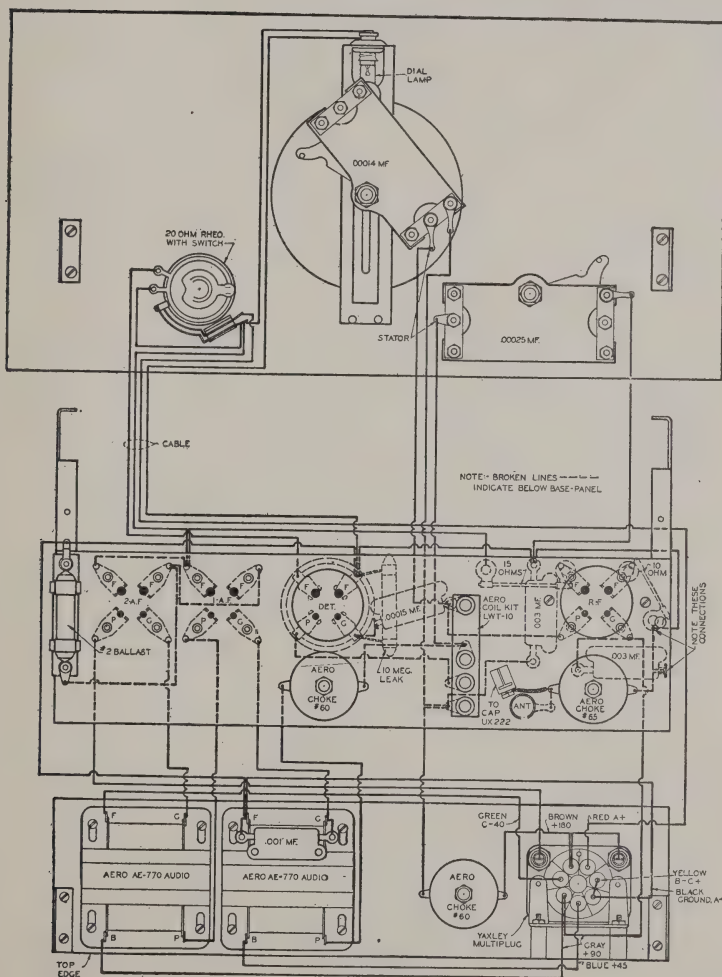


Fig. 50

of the plate supply. A .003-microfarad condenser is used to by-pass between the secondary coil and the negative filament circuit. The feed-back is controlled by means of a variable condenser connected between the tickler coil and the negative filament.

The resistors placed in the filament leads for the shield grid tube are for the purpose of dropping the voltage in the filament circuit, the filament for the shield grid tube requiring 3.3 volts maximum while a 5-volt supply is delivered to the set.

Two-Stage Short-Wave Converter. The circuit for the two-stage short-wave converter employing the shield grid tube in the antenna stage shown in Fig. 51 is identical with that shown in Fig. 49 except that the audio stages have been eliminated. The circuit is shown pictorially in Fig. 52.

Direct-Current Short-Wave Converter. The direct-current short-wave converter is a device that can be connected into the detector socket of a standard direct-current receiver so that the audio stages of the receiver can be used to give loud speaker volume to the reception.

The schematic diagram for the converter is shown in Fig. 53 and the pictorial layout and wiring diagram in Fig. 54. The circuit is essentially the same as those already shown, the variation being the method of regeneration control. The method of controlling regeneration may be left to the discretion of the builder, and the method shown here is merely for the purpose of furnishing more than one system whereby the same result can be obtained.

The tickler coil is connected to the filament circuit through a .0005-microfarad fixed condenser. An 8,000-ohm rheostat is then connected across the terminals of the tickler and the variation of the amount of resistance varies the plate output impedance so that the amount of energy that is permitted to flow back through the tickler coil is controlled. As the resistance becomes higher, more current will flow through the coil; and as the resistance becomes less, more current will be dissipated by the resistor unit.

The base of an old tube is needed for making the connections to the set. Remove the glass and by means of a soldering iron remove the old leads from the tube. Solder leads into the two-filament and the plate prongs, connecting them to the respective terminal posts on the converter.

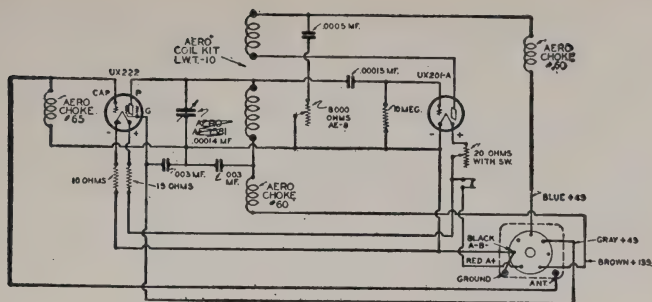


Fig. 51

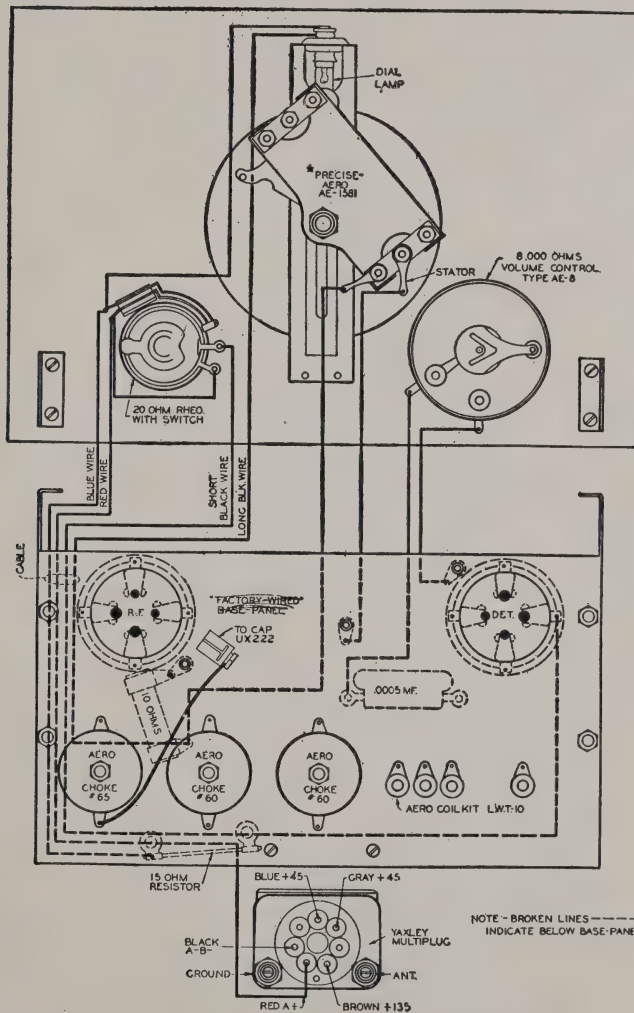


Fig. 52

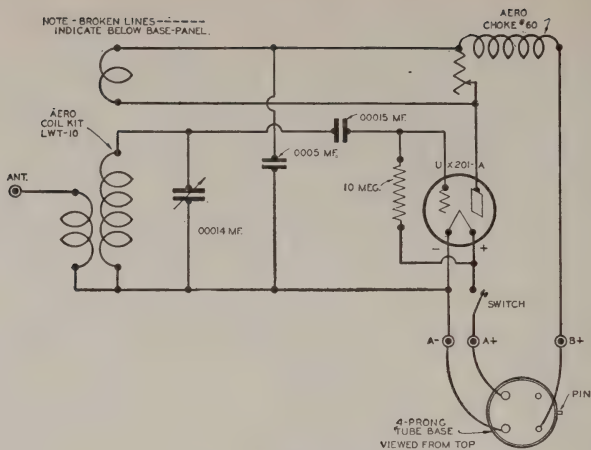


Fig. 53

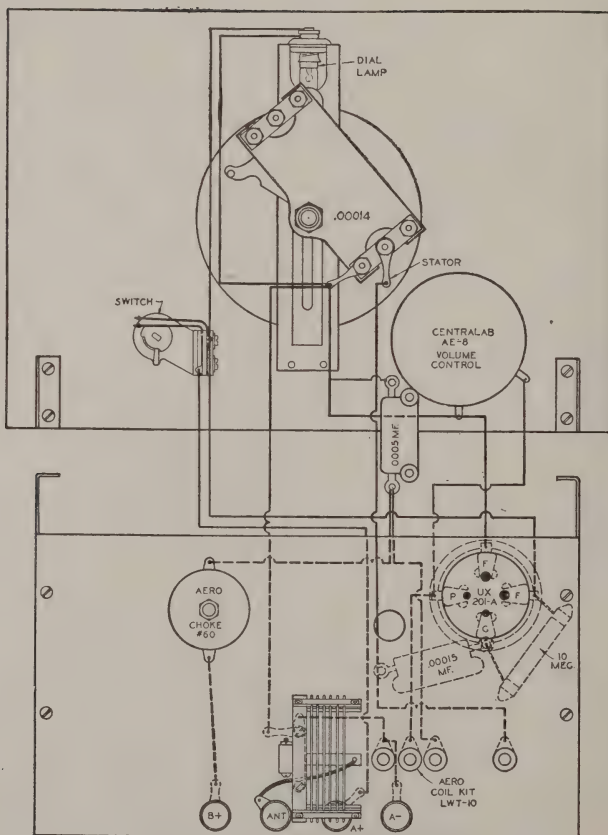


Fig. 54

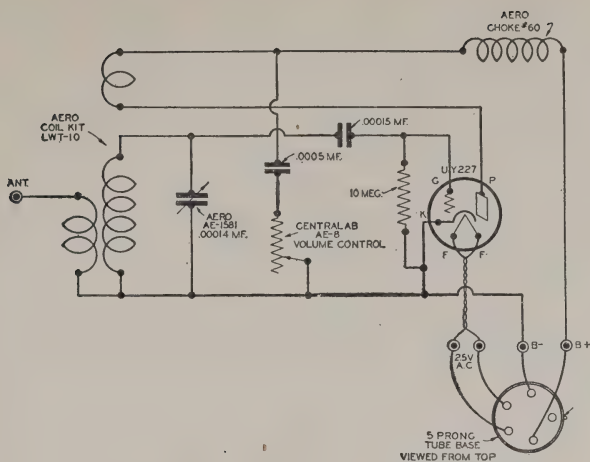


Fig. 55

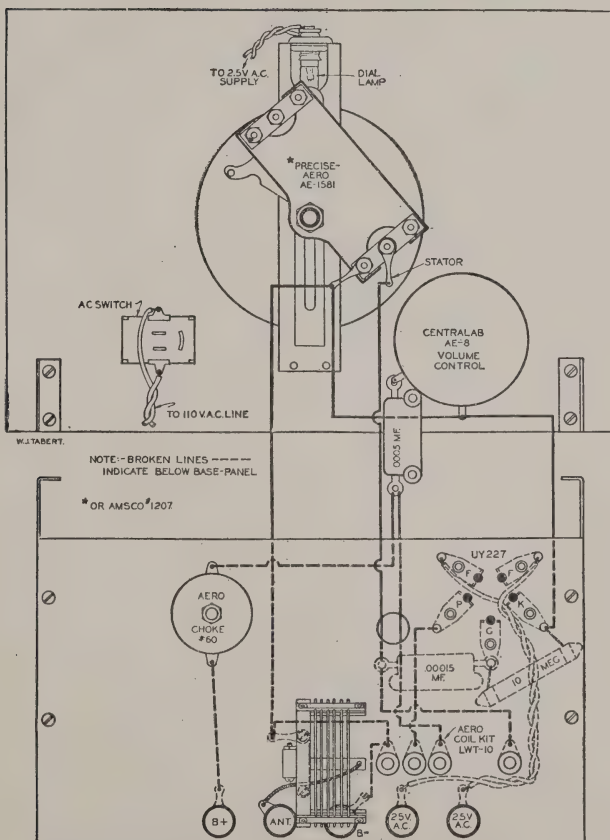
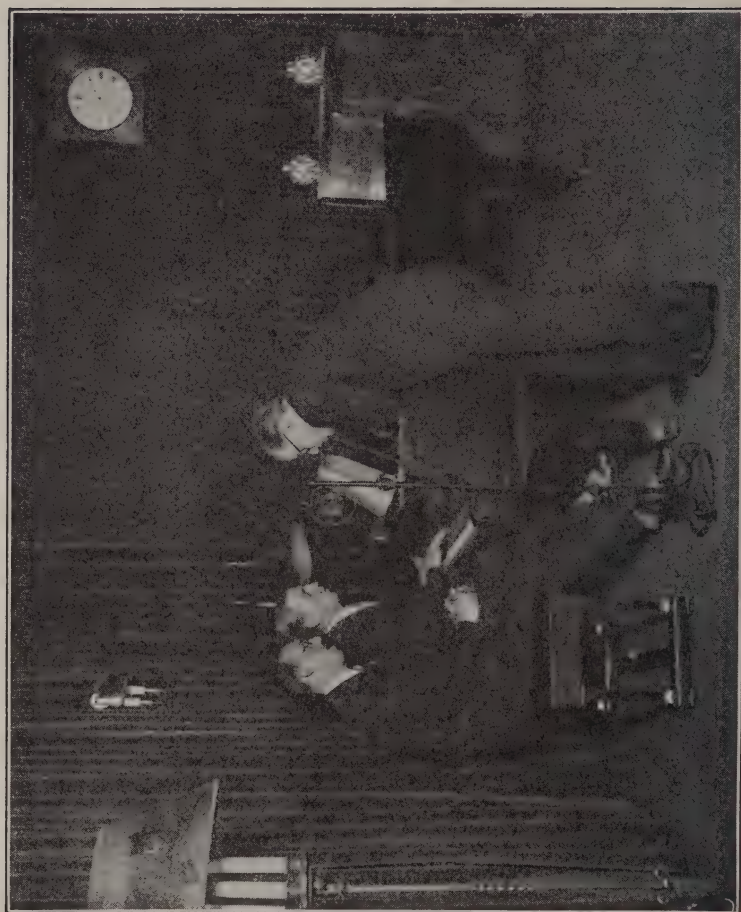


Fig. 56

When using the short-wave converter with a radio receiver, the radio frequency stages of the set are inoperative.

Alternating-Current Short-Wave Converter. The alternating-current short-wave converter serves the same purpose as the direct-current converter and the principle of the circuit is the same, as will be seen by referring to Fig. 55. The circuit shown in Fig. 53 is changed so as to be adaptable to the use of the heater type of alternating-current tube. The pictorial diagram and layout shown in Fig. 56 gives the necessary information for constructing one of the units.

In connecting the alternating-current short-wave adapter to a set, it is necessary to have the base of a UY-227 tube to fit into the detector socket of the alternating-current set. The connections to the base are shown in Fig. 55. No connection is made to the grid terminal so that the stages of the set ahead of the detector are inoperative. The negative B lead is connected to the cathode terminal of the tube base.



MUSICAL POT POURRI OVER WMAQ, HOTEL LASALLE, CHICAGO

THE DYNAMIC SPEAKER

Introduction. The dynamic speaker as it is known is erroneously named, but it has carried the name since 1921 so that now the nomenclature has been adopted by radio engineers as well as the laymen. Electrodynamic would be a term more adaptable to the device, and even that designation would not be correct in every sense of the word. When the action of the speaker is analyzed, it would seem more proper to call it the moving coil unit.

Be that as it may, the unit was introduced to the radio public as a dynamic speaker and, in spite of the protests of radio engineers, it has continued to be known by that name. Therefore, in the following discussion, although not in accord with the author's own conception so far as name is concerned, the speaker shall be referred to by its common designation, the dynamic speaker.

Speakers in General. The function of any radio loudspeaker is to convert electrical waves into sound waves. The conversion is accomplished in a double action. The electrical waves act to move a diaphragm which displaces the air within a confined area. The air thus set in motion creates a succession of waves that correspond to the sound impulses at the point of origin where the sound waves were first converted into electrical waves by their contact with the diaphragm of a microphone. Crumple a piece of paper and a crackling sound is heard. The noise which occurs is the result of the breaking up of the air surrounding the paper and is not caused by the paper itself.

In order to gain a better perspective of the operation of a dynamic speaker, the action of the magnetic and balanced armature types of speaker units will be briefly explained. Fig. 1 shows a magnetic type of speaker unit. It consists of a permanent magnet M to which are attached two extension arms A , upon which the coils $C-1$ and $C-2$ are placed. The diaphragm D is a thin sheet of steel which is held away from the magnets by the periphery of the case into which the entire assembly is fastened. A cap over the case serves to hold the diaphragm in position so that it cannot move except for the vibrations on the inner section of the disc.

The output from the receiving set is delivered to the loudspeaker unit through wires connected to terminals *T-1* and *T-2*, to which the outer end of one of the coils and the inner end of the other coil are connected, respectively. The inner end of the first coil and the outer end of the second coil are then connected together so that the two windings are connected in series, and the impulse that flows through the circuit is evenly distributed through both coils.

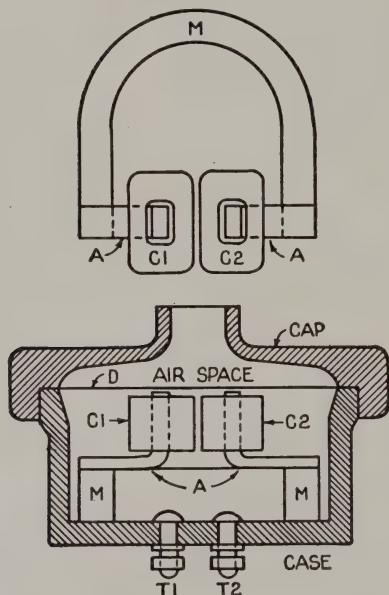


Fig. 1. Magnetic Type of Speaker Unit

The output from the receiving set fluctuates according to the intensity of the sound waves that strike the diaphragm of the microphone at the transmitting station. The fluctuating current in passing through the windings of the loudspeaker unit act upon the magnetic field that naturally surrounds the permanent magnet *M*, so that the intensity of the magnetic field is alternately augmented and decreased. The steel diaphragm *D* is drawn toward or pushed from the magnets in response to the intensity of the magnetic field, and the vibrations set up a succession of waves that strike the eardrum where they are translated into sound.

The next step in loudspeaker design is known as the balanced armature type, shown in Fig. 2. What had served as the diaphragm in the magnetic type of speaker was put into different form, and now became an armature, acting in much the same manner as the armature of a motor. Confined within a narrow space the armature is not permitted to revolve, and in order that it can

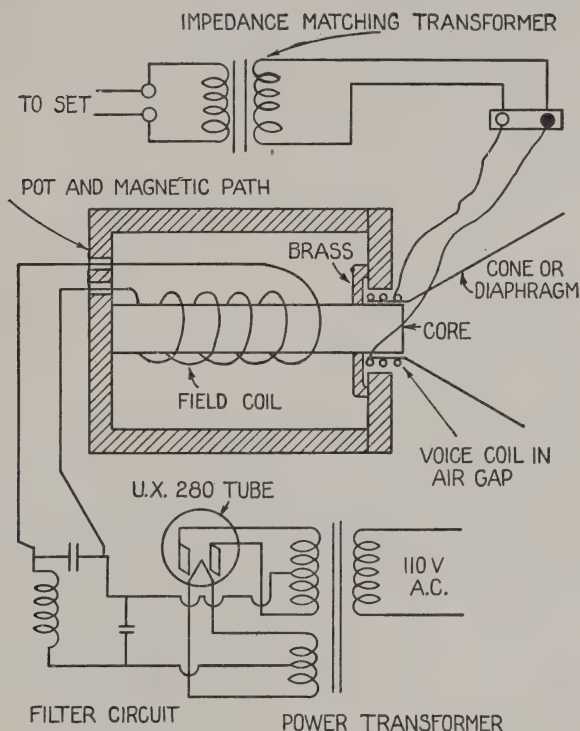


Fig. 2. Balanced Armature Type of Speaker Unit

respond to the current impulses it is balanced either centrally or at the ends. Fig. 3 shows an armature which is balanced near the center. The armature is not only small in comparison to the diaphragm of the magnetic unit, but it is also placed in such a position that little air is available and there is no opportunity for it to set up sound waves. Hence, it must be attached mechanically to a larger diaphragm whose sole purpose is to stir the air and emit volumes of sound waves. A cone-shaped diaphragm of paper or

cloth became prevalent, so that the balanced armature type of speaker became known as the cone speaker.

The principle upon which the balanced armature type speaker functions is considered to be dynamic, while others more critical as to nomenclature claim that it is electrodynamic. The armature of the cone type speaker vibrates in response to the electrical impulses that pass through the coils mounted on the poles of the magnet. With the fulcrum in the center there is a double action, in that one pole of the magnet has the effect of pulling one end of

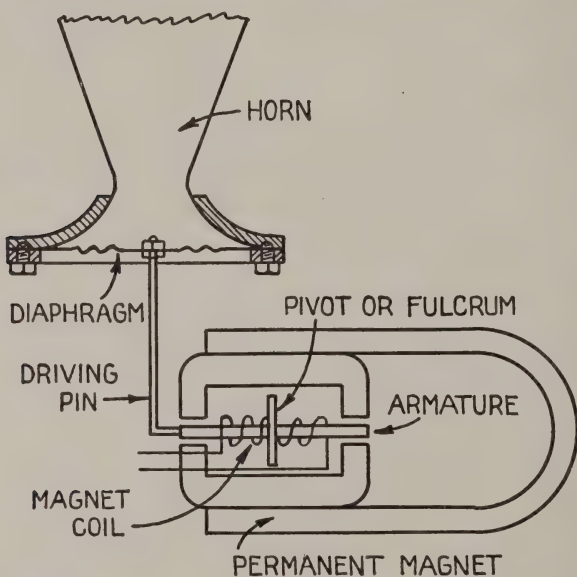


Fig. 3. Type of Speaker Unit with Armature Balance near Center

the armature while the other pole of the magnet whose polarity has been strengthened by the current pushes the other end of the armature and causes the vibration to become more pronounced.

Fig. 4 is one of the latest models of the balanced armature type of speaker. The detail drawing shows the shape of the fulcrum.

The Dynamic Speaker. The dynamic speaker differs from the foregoing types in that the permanent magnet is removed and an electromagnet is used instead. An electromagnet is one which becomes a magnet only when a direct current is passed through a coil which surrounds the soft iron serving as the core.

The best way to understand the action of the dynamic speaker is to perform a few simple experiments in elementary magnetism. Fig. 5 shows a solenoid coil, which can be made by winding a few turns of any size wire on a pencil. Secure an ordinary dry cell and connect one end of the coil to one terminal of the dry cell. If

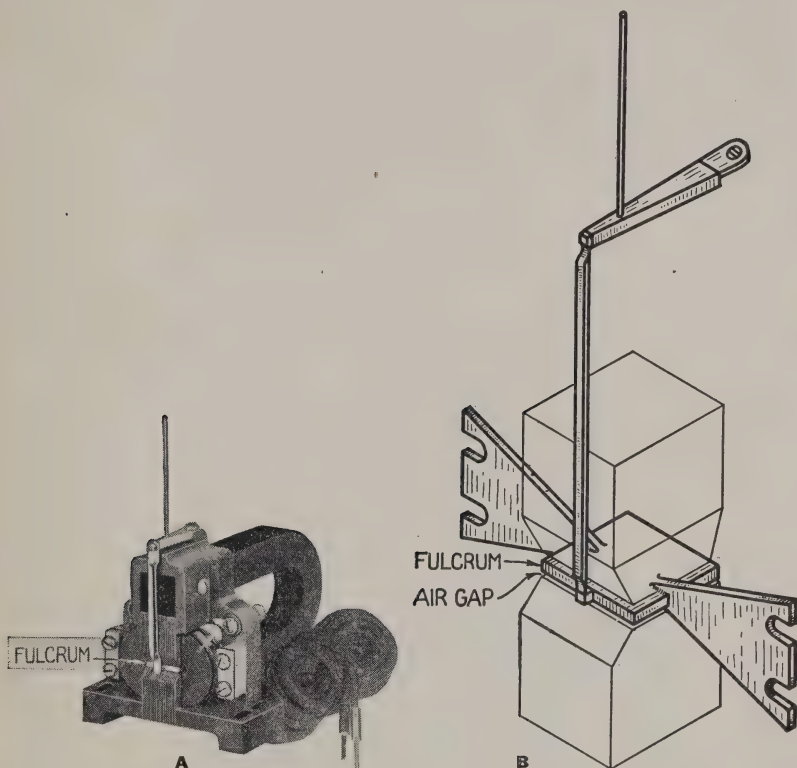


Fig. 4. A—Balanced Armature Type of Speaker Unit
B—Detail of Fulcrum and Air Gap

the other end of the coil is touched to the other terminal of the dry cell, no action will be noted. Do not allow the circuit to be completed for any length of time, for the wire will be heated by the current from the dry cell.

Next set up the apparatus shown in Fig. 6. One dry cell will suffice for this experiment also, but three cells will give more strength, and the results of the experiment will be more pronounced. A

telegraph key is desirable as a means for opening and closing the circuit, but in the absence of the key a piece of brass stripping and a couple of screws can be mounted on a board so that the circuit can be broken quickly. Two nails, one a 20d spike and the other a small shingle nail, should be procured. If a piece of soft iron

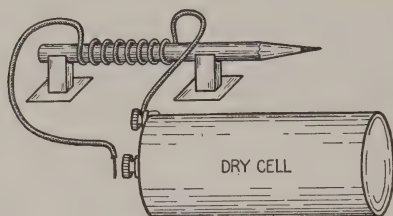


Fig. 5. A Simple Solenoid Coil

bar is handy, it will serve the purpose as well and perhaps better than the spike. Any other piece of steel or iron will take the place of the shingle nail, but nails are usually found in any home.

Support the spike by two pieces of string, as shown in the diagram. Slip the solenoid coil over the spike and connect one

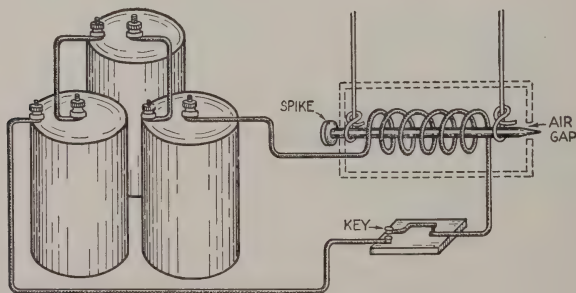


Fig. 6. Set-up for Experiment in Electromagnetism

end to the positive terminal of the battery. The other end of the coil is connected to one terminal of the key, while the other terminal of the key is connected to the negative terminal of the battery. Now close the key and as the current passes through the coil the windings will be seen to spring together. Break the contact and the coil will assume its original shape.

Place the small nail in one hand and operating the key with the other, note the distance that the small nail can be made to jump when the current is passed through the coil. Here we have an example of electromagnetism. The current passing through the coil sets up lines of force that pass into the spike and magnetize it temporarily. Being soft, it loses its magnetism quickly so that when the current is shut off, the load will drop because there is not enough magnetism to hold the weight.

To further explain the electromagnetic action, let us go back into some other explanations found in elementary electrical engineering. When an electrical current is passed through a wire,

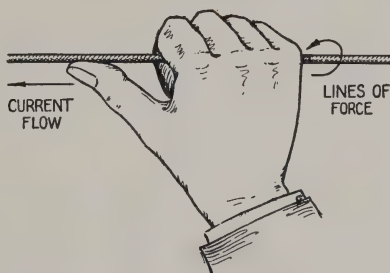


Fig. 7. Fleming's Right-Hand Rule Showing Direction of Current and Lines of Force

energy is radiated and what is known as a magnetic field is established. If the current varies in the direction of flow, as in the case of alternating current, the field is varied in accordance with the pulsations of the current. A direct current passed through a conductor establishes a current which remains constant, due to the fact that the current is flowing in the same direction. The magnetic field is composed of what are known as lines of force which have a definite direction of flow as determined by the direction in which the current is flowing in the conductor. The direction in which the lines of force travel is determined by Fleming's right-hand rule shown in Fig. 7. The thumb of the right hand points in the direction in which the current is flowing and the fingers wrapped around the wire point in the direction of the lines of force.

A single conductor has little magnetic effect and, in order to centralize the energy, it is necessary to form the conductor into a

coil. The lines of force are then traveling around each turn of the coil and there is a flow of the lines of force or magnetic flux inside the coil, returning on the outside of the coil. With a coil wound and connected as shown in Fig. 6 the magnetic flux would flow from the point of the spike toward the head, since the current from a battery flows from the positive to the negative in the external circuit.

These simple experiments form the nucleus from which to determine the action of the dynamic speaker, and we go into the next step. Referring again to Fig. 6, the dotted lines indicate an iron shield fastened to the head of the spike, surrounding the coil, and supported in such a manner that it does not come in contact with the point of the spike, forming an air gap between the spike and the shield. The shield is fastened directly to the spike at the head end. Here we have a definite path for the lines of force in their return to the other end of the coil.

If the coil were built to carry the current delivered by the battery, a closed circuit would now create a magnetic field that would flow from the point of the spike to the head, through the shield, back across the air gap to the point again. By providing the shield, the air through which the lines of force must pass is materially lessened and the strength of the flux is naturally strengthened.

Assume that a small coil could be inserted in the air gap space. If it were connected into a circuit equipped with a meter and provision made to vibrate it back and forth over the end of the spike, a current would be set up within the circuit containing the small coil, as indicated by the meter. The value of the current would depend upon the size of the coil and the speed with which it was made to cut the lines of force in the air gap.

Compare the diagram shown in Fig. 6 with that shown in Fig. 8. Fig. 8 is the cutaway view of a dynamic speaker unit. It consists of a core, a field coil, a pot, a voice coil, and a diaphragm, each of which are indicated on the illustration. The core of the speaker unit corresponds to the spike used in the experiment. The field coil is an enlargement of the solenoid coil; the pot takes the place of the shield; and the voice coil substitutes for the small coil mentioned at the end of the experiment. A brass collar at the air gap end holds the core centered. The brass is not affected by

the flow of the magnetic flux and is not itself a conductor of magnetic lines of force.

But the action of the dynamic speaker does not follow the procedure described above. The difference lies in the action of the voice coil, which has no mechanical means for causing it to vibrate but does vibrate from causes contained within the unit itself.

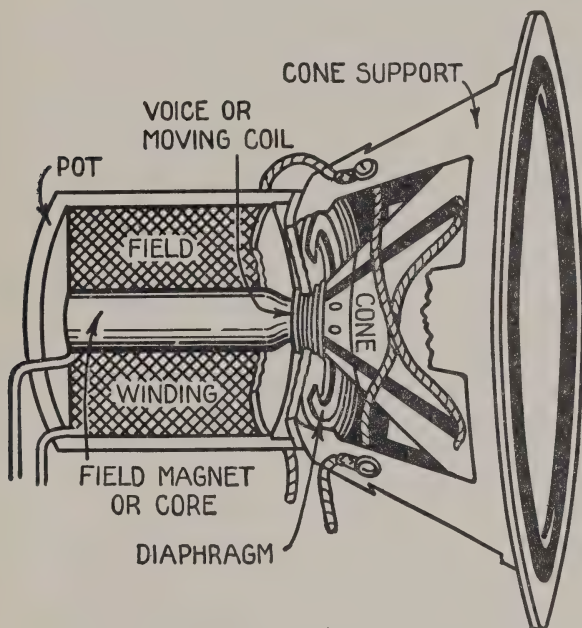


Fig. 8. Cutaway View of a Dynamic Speaker Unit

The electrical energy that is delivered to the field coil must be direct current. Alternating current will not serve, since the reversals of the current would cause the magnetic field to build up and collapse with each cycle. The flux would then flow first in one direction and then in the other. The voice coil would follow the vibrations of the current as closely as possible, the flexibility of the cone determining its ability to do so.

Radio apparatus having taken steps toward socket power operation, it became necessary for the speaker designers to provide the units with a rectifying agency for those speakers designed to derive their

power directly from the alternating-current light socket. Another means of providing the direct current to the field coil is through the voltage divider circuit of a power unit to furnish 110 or more volts of direct current from the same source as that provided to supply the plate energy to the receiving set. With the increased use of the alternating-current type of speaker units, the radio set manufacturers adopted the policy of installing a receptacle in the set into which the leads to the speaker might be connected to provide a control for the field coil simultaneous with the turning on and off of the set.

The rectifier circuit, which is a part of the speaker, consists of a transformer, a rectifying agent, and a filter circuit. The type of rectifier varies, but it is essential that it be of the full-wave type. The disc type rectifiers are used in many of the earlier models of the modern speaker units, but many such agents have been supplanted by the full-wave rectifier tube. The disc rectifier supplies the field coil with a low voltage at high current, while the rectifier tube supplies a high voltage at low current. There is no advantage of one over the other from an operating standpoint, but the rectifier tube is more readily obtained and can be replaced by the most inexperienced set owner.

The output of the set could not be supplied directly to the windings of the voice coil, because that winding is comparatively small. One manufacturer uses a single turn of heavy stripping instead of a number of turns of wire, claiming that the use of a single turn of heavy copper strip provides more rigidity than the smaller wire. Rigidity is an essential characteristic of the voice coil, and the smallness of that part of the unit makes it difficult to meet the requirement. If the voice coil is not rigidly constructed, there is danger of it slapping against the end of the core at one or more points in the frequency range.

In order to adapt the speaker to the receiving set an impedance matching transformer is connected into the circuit. The ratio of the transformer is one to one, but the impedance of the primary winding is an average of that found in power tubes of the modern type, while the impedance of the secondary winding matches that of the voice coil. The result obtained is the same as though the voice coil were given an impedance to match that of the tube itself.

When the electrical energy is fed into the field coil, the magnetic flux travels through the pot across the air gap and through the core. The voice coil placed in the air gap will not be affected until some value is changed to cause a flurry in the passage of the lines of force. A varying impulse passing through the voice coil from the receiving set sets up a varying field surrounding the windings of that coil and coming in contact with the flux present in the air gap. The voice coil moves, since it is the only part of the assembly that is not made fast. The voice coil is cemented to the diaphragm, which is cone-shaped, but the cone is fastened flexibly to the frame which supports it.

If the current supplied to the field coil were shut off, the speaker would continue to function, but with reduced amplitude. The reason for its functioning at all is due to the field that is set up around the windings of the voice coil which act against the iron core just as was the case when the coil was placed around the spike and the battery current passed through it.

Some dynamic speakers will rattle at certain definite frequencies and when such a condition exists, the speaker is defective in that the cone is not centered properly or that the voice coil is not rigid enough to prevent it vibrating to such an extent that it strikes the sides of the core. Usually the difficulty is caused by improper jig work during assembly, and there is no way in which to remedy the situation other than to replace the cone with one properly constructed.

Through the courtesy of the Leslie F. Muter Company of Chicago, it is possible to show the integral parts of a dynamic speaker. The speaker shown is one of the type which employs a full-wave rectifying tube to supply the direct current.

Fig. 9 shows the pot construction of the speaker together with the cone and the outer frame which holds the cone in position and maintains its relationship with the field coil assembly. The centering spring which appears in the illustration must be very flexible in order that it will not retard the action of the cone and at the same time it must be strong enough to hold the voice coil rigidly in the center. A thin sheet of Bakelite is used in the speaker illustrated. Others use thin brass or steel. Notice the terminal strip on the outer frame. The connections from the output transformer

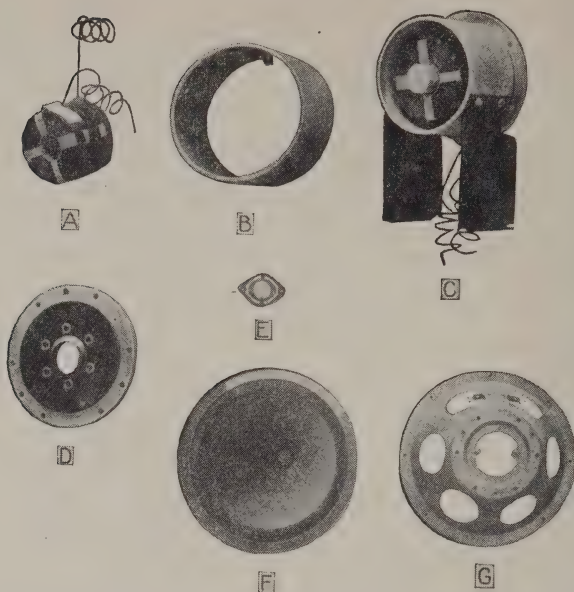


Fig. 9. A—Field Coil; B—Pot Shield; C—Assembly of Pot, Core, and Field Coil with Mounting Brackets; D—Pot Cover, Showing Brass Ring Riveted to Center; E—Centering Spring to Maintain Relationship between Voice Coil and Core; F—Cone Assembled (Note the small form in apex upon which the Voice Coil is wound); G—Cone Support

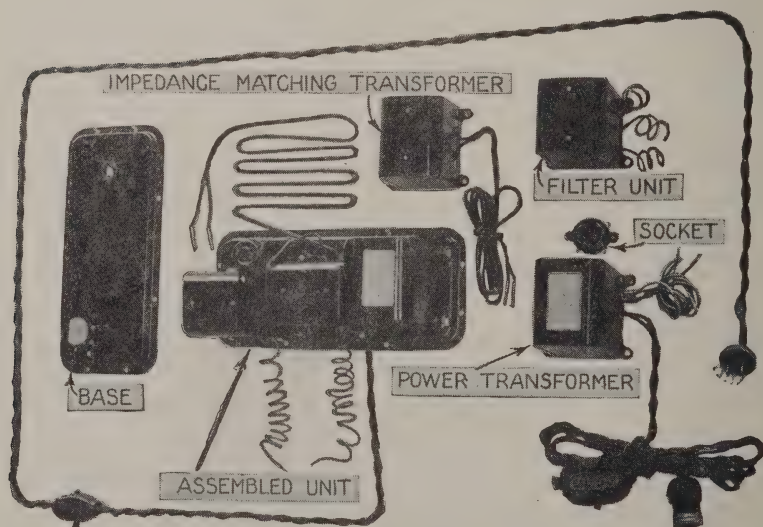


Fig. 10. Apparatus in the Rectifier Circuit

and thence to the voice coil are made from this strip, permitting the use of solid wires extending from the transformer and extremely flexible wires to the terminals of the voice coil. Fig. 10 shows the parts that are mounted on the base, including the rectifier socket, the filter, and the impedance matching transformer.

The Baffle. A discussion of the baffle to be used with a dynamic speaker would entail a lengthy discussion of acoustical engineering. Suffice it to be said in this discussion that there are two sound waves set up by the cone of a dynamic speaker, one from the front and the other from the rear of the cone, and that one of the purposes of the baffle is to prevent a collision between the two waves.

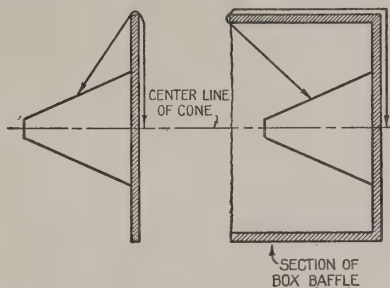


Fig. 11. Flat and Box Type Baffles

Such a collision would result in the neutralization and consequent distortion or wiping out of the tone desired.

There are two types of baffles, the flat and the box type. The box type baffle should be well vented at the rear so that the sound waves will not rebound against the rear edge of the cone, and for the same reason the speaker should be kept a few inches from a wall where there would be a tendency to set up distortion through the reflection of the sound waves.

The reproduction of low tones is dependent to a certain extent upon the size of the baffle. Fig. 11 shows the flat and the box type baffles and how they can be measured to find if they will reproduce tones as low as those desired. A speaker with a baffle measuring approximately 32 inches will reproduce a tone of 100 cycles, while it is necessary to provide a 64-inch baffle to secure a 50-cycle note. Tones lower than 100 cycles are not often desired outside the laboratory.

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